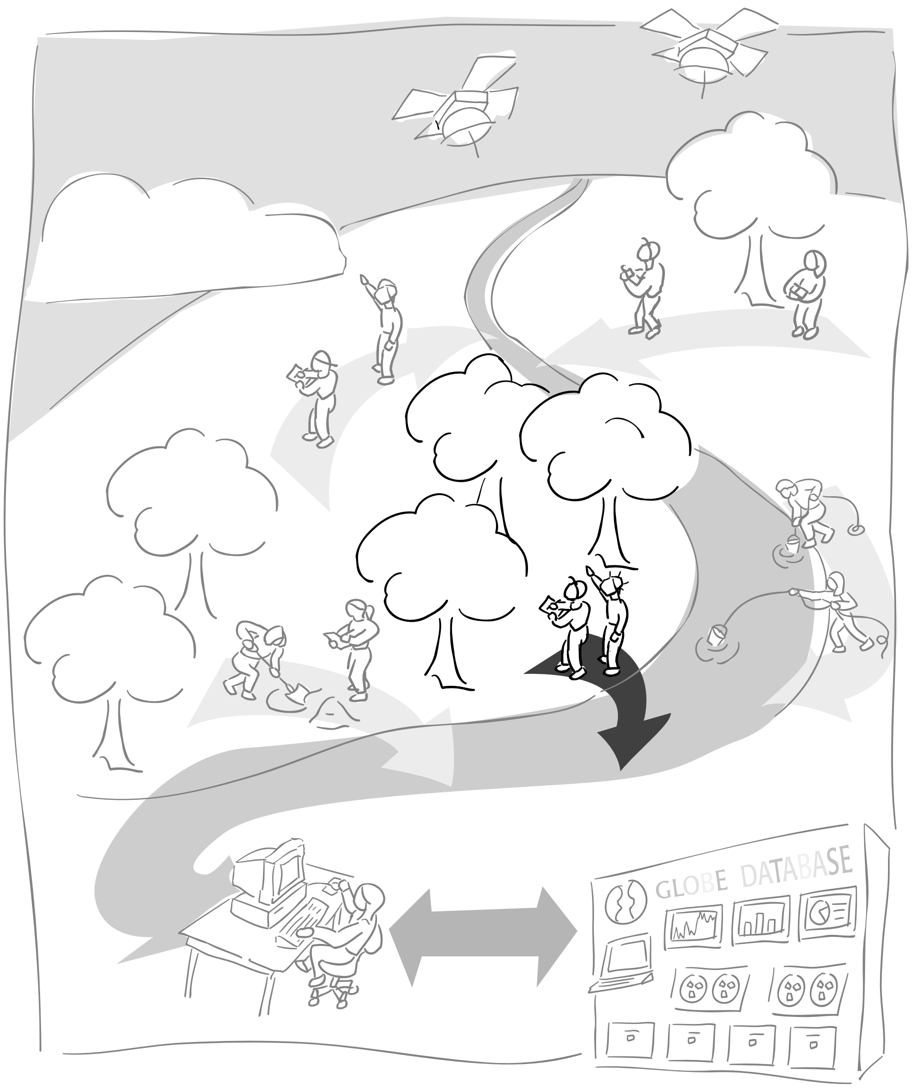
Land Cover/Biology Investigation



A GLOBE™ Learning Investigation

TM

Land Cover/Biology Investigation at a Glance

Protocols

Identify the general land cover type to MUC level 1

Qualitative Land Cover Sample Site Protocol

Data collected once for each land cover sample:

GPS location, photos of sample, determine MUC class

Quantitative Land Cover Sample Site Protocol

Data collected once for each land cover sample:

GPS location, photos of sample, biometry measurements, determine MUC class

Biometry Protocol

Data collected once or twice per year for Biology Study Site, once for the Quantitative Land Cover Sample Sites

Determine dominant and co-dominant vegetation types

Biometry measurements: tree height and circumference, grass biomass, canopy cover, and ground cover

MUC System Protocol

Manual Interpretation Land Cover Mapping Protocol

Unsupervised Clustering Land Cover Mapping Protocol

Accuracy Assessment Protocol

Create a difference/error matrix, calculate overall accuracy and interpret results.

Suggested Sequence of Activities

[Certain Learning Activities are desirable prior to implementing Protocols]

Read *Remote Sensing* found in the *Implementation Guide*

Read the *Scientists' Letter* and *Interview* with your students

Select a site and identify the general land cover type to MUC level 1

Perform *Qualitative* or *Quantitative Land Cover Sample Site Protocols*

Pre-Protocol Learning Activity: *Site Seeing*–introduces systems concepts

Perform *Biometry Protocol*, set up Biology Study Site

Pre-Protocol Learning Activity: *Leaf Classification* introduces the concepts of classification

Perform *MUC System Protocol*

Pre-Protocol Learning Activities: *Odyssey of the Eyes*; introduces remote sensing and *Some Like It Hot* introduces false-color images

Tutorial: *Manual Interpretation* from *Toolkit*

Tutorials: *Introduction to MultiSpec* and *Unsupervised Clustering Tutorial* if you will be doing computer image processing

Perform either *Manual Interpretation Land Cover Mapping Protoco*l or *Unsupervised Clustering Land Cover Mapping Protocol*

Post-Protocol Learning Activity: *Discovery Area*–using images students create

Pre-Protocol Learning Activity: *Introducing the Difference/Error Matrix or What's the Difference?*

Perform *Accuracy Assessment Protocol*

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Scientists' Letter

GLOBE Teachers:

Hello and welcome to the new Land Cover and Biology research materials! Actually, they are not entirely new – GLOBE teachers and students have been doing biometry in their "pixel" study sites since the beginning of the program. Some classes have also been interpreting satellite images of their local area, although this wasn't a formal "protocol" until now. What we have attempted in this new set of materials is to tie together biometry measurements with observations of cover type in a number of ground sites, and with land cover mapping of your area using the satellite imagery provided to you by GLOBE. In the process, we have added biometry protocols for grasslands in addition to trees, and procedures for evaluating the accuracy of land cover maps – an important aspect of the science of remote sensing and global monitoring. We have also adopted and modified a new classification system for land cover which we hope will be more comprehensive than the system used previously. The goal is to involve you and your students in all phases of our research in remote sensing and land cover mapping at the University of New Hampshire. Please let us know how we are doing, and what you think of the new materials.

Best Regards,

The Land Cover/Biology Co-Principal Investigators:

David S. Bartlett	*Russell G. Congalton*	*Janet W. Campbell*
David S. Bartlett, PhD	Russell G. Congalton, PhD	Janet W. Campbell, PhD
Eleanor Abrams	*Mimi L. Becker*	
Eleanor Abrams, PhD	Mimi L. Becker, PhD	

Meet the Land Cover/ Biology Team

Duplicate and distribute to students.

This section represents a combined effort between the Biometry and Accuracy Assessment teams at the University of New Hampshire to form the Land Cover Investigation. Dr. Russell Congalton is the science Principal Investigator and Dr. Mimi Becker is the education Principal Investigator for the Accuracy Assessment Team. Dr. David Bartlett is the science Principal Investigator and Dr. Eleanor Abrams is the education Principal Investigator for the Biometry team. Mr. Gary Lauten is a project scientist with the Biometry team. This interview is with these members of the Land Cover Investigation.

Dr. Congalton: I deal with satellite data, aerial photography, and remote sensing or mapping land cover pretty much all over the world. My degrees are in forestry. People don't think of forestry as a science, but it's very science-based and interdisciplinary. You need physics, computers, biology, statistics and math in order to put it together.

GLOBE: When I think forestry, I think being out there in the forest—

Dr. Congalton: —and playing chess with Smokey the Bear.

GLOBE: And being in a tower overlooking the wilderness. Now you're at a university. What was your image of forestry back then?

Dr. Congalton: It wasn't Smokey the Bear. I never thought that I would live in the middle of nowhere and wash my clothes in a stream. I still get to go to the woods on a regular basis. I like being in the office when it's raining or snowing. I like playing on the computer.

GLOBE: Do you spend time in a laboratory?

Dr. Congalton: My laboratory is the computer laboratory. The computers allow us to do statistical analyses as well as manipulation of the satellite data, the aerial photography, for our mapping purposes.

GLOBE: Is most of the information you're working with from the sky?

Dr. Congalton: Yes, but we need to verify the satellite data with what's happening on the ground. There are some things you can't tell from satellite data, like a species of plant that's too small for satellite photographs to capture. We want to validate the maps made from remotely-sensed data over the last few years so we can see what's changing on the Earth. We've never determined how good the satellite data or photography is for a lot of areas. We need to know how good the remotely-sensed satellite data is in order to verify the decisions we make based on this data.

GLOBE: What kind of decisions?

Dr. Congalton: There are many estimates of land cover in the Amazon. There's actually never been an accurate assessment of this. People publish figures saying, "X amount of trees are being cut a day," but there's never been an accuracy assessment to determine if that's really true.

Dr. Bartlett: We're using computer models and our knowledge of, for example, how plants utilize sunlight, water and nutrients in order to simulate and ultimately predict the behavior of ecosystems. GLOBE students can help. In trying to replicate conditions of a particular area, for example, you need to know what kind of vegetation is there and its environmental conditions. The GLOBE data provides that information. GLOBE is also important for validation. Validating models is a process of running the model and comparing the results to measurements in the real world.

GLOBE: By modeling, we're talking about predicting the future given certain parameters?

Dr. Bartlett: Predicting change. What if I change the average annual temperature by five degrees? Or reduce the average annual precipitation in this region by 50 centimeters? Put that into the model and see what it predicts. That's the real power of modeling, but it relies on comparing the output to real data, and the only real data we currently have is from our limited resources and the data from students.

GLOBE: What is remotely-sensed data?

Dr. Bartlett: In the context of GLOBE, we're primarily talking about satellite data. Satellites have an advantage in that they collect data for long periods of time. This is what is needed for global environmental monitoring.

GLOBE: What is the satellite actually seeing or measuring? Can it detect vegetation? "Hey, that's green. That must be grass?"

Mr. Lauten: A satellite doesn't know what it sees. All it sees is a brightness from a portion of the ground. Landsat sees visible plus near infrared and middle infrared radiation. Essentially it can see what your eyes see, as well as the near infrared and middle infrared.

GLOBE: Have students ever helped verify satellite data?

Dr. Congalton: Not that I know of. And certainly not at GLOBE's scale.

GLOBE: A common perception of scientists is they're lone-wolf types working in their laboratories late at night. But that doesn't seem to be the case here. Here it's collaborative. Why is that?

Dr. Becker: We're dealing with complex systems at the global and local levels. Most of the work we do is interdisciplinary, so we have to work together to solve problems.

Dr. Bartlett: GLOBE is a unique collaboration between science and science education. No one person can provide expertise in all the facets of world-class environmental science as well as science concepts for young students. It's common for people in our line of work to work with scientists in other disciplines.

GLOBE: What question are you trying to answer with the GLOBE data?

Dr. Bartlett: How the Earth as a whole system works. However, the Earth is very complex. One way to simplify that problem is to look for processes that link those diverse parts of the system. For example, there are a small number of important materials, compounds and nutrients that living things in one way or another need and use during their lifetimes. Those include water, carbon, nitrogen, sulfur, sunlight. All plants, whether they be in arid environments or tropical environments, need some combination of those to exist. So we investigate the cycling of those materials to try to produce a picture of how vegetation operates. And although it can't do everything, remote sensing has a role to play in that.

Dr. Becker: As a policy scientist, I'm concerned with how people relate to the ecosystem. How can we maintain healthy regional and global systems in the face of continuing human stress? Where we have severely impaired systems, are there ways we can constrain human behavior so that basic ecological functions are restored? What kinds of decisions does that involve? What kind of information do we need to change policy and educate people?

GLOBE: You are a policy scientist?

Dr. Becker: I'm a natural-resource and environmental-policy scientist, so I'm interested in relationships between humans and their communities, and the Earth systems that support them.

GLOBE: As a woman, what were your attitudes toward science when you were in middle school and high school?

Dr. Becker: They evolved. I came through a period of time when women were not expected to do either science or math. I still have a certain amount of math phobia, although I can do it when I have to. My father was a photographer and I fooled around with chemicals and worked in darkrooms.

GLOBE: What are you going to do with your findings?

Dr. Becker: For example, there are issues that relate to water shortages or land-use activities. The only way they're going to get solved is locally. So I'll be looking to collaborate with students in those areas where I know problems exist. We'll try to understand what's going on and how that's related to the local policy and management. My interest is in training people how to research so they can acquire information, interpret it, and apply it to problem-solving at the level of their own regions or watersheds.

GLOBE: When you talk about acting locally, do you mean talking to local scientists? Governments? Businesses?

Dr. Becker: One way that we have begun to solve some serious problems is to link the scientists, the regulators, the polluters and the people who have a stake in healthy living in the bioregion. There are GLOBE students who are sitting down with people in their communities and saying, "Look, we have a problem. How can we work together to solve it?" So I look at how the system works, what people need to know and how can they get that information to solve the problem.

GLOBE: *Is science at the root of this kind of change?*

Dr. Becker: Absolutely. Science is where you start to understand the problem. You have to get at its causes and effects, and then assess how to address it. Science is essential as a systematic approach to the acquisition of information and its evaluation.

GLOBE: *How does science acquire this information?*

Dr. Bartlett: One way is to set up networks of data collection. To give you an example, back in the 1950s, when David Keeling set up a monitoring station for carbon dioxide concentrations in the atmosphere in Mauna Lau, Hawaii, nobody had any idea that we had already begun to affect global atmospheric carbon dioxide concentrations. It was only after 15 or 20 years of data collection that people began to see this clear trend of increasing CO_2 levels. With GLOBE sites, we may well be able to identify trends.

Dr. Bartlett: One way GLOBE will be influential is by educating the students who will someday be policy makers. They will be the politicians who will hopefully make better-educated decisions than are currently being made because they've been introduced to science; they've studied their own environments; they've taken these measurements; and they know how the data is interrelated. I think they will have a much better understanding than we did when we were kids.

Introduction

The Big Picture

The type and amount of land cover in an area are important characteristics from the standpoint of understanding the Earth as a system - the cycles of energy, water, and chemical elements essential to life such as carbon, nitrogen, sulfur, and phosphorous. In the energy cycle, land cover influences the reflection of solar radiation from the land surface. This in turn influences the heating of the atmosphere and local and regional climate patterns. The resulting patterns in atmospheric temperature influence the kinds of plants that can live in an area and this largely determines the type of natural land cover. In the water and biogeochemical cycles, variations in the type and amount of land cover influence the cycling of water, carbon, nitrogen, and sulfur among the soil, plants and atmosphere.

Since the mid-1980's, an area of research known as Earth system science has developed to study and understand these processes and the interactions among the atmosphere, *hydrosphere*, *biosphere*, *geosphere*, and *cryosphere*. GLOBE students will be mapping land cover and providing ground observations which will advance their own understanding of the landscape around them as well as the research of Earth system scientists. This mapping involves distinguishing the types, or classes, of cover on the surface.

There are many systems for classifying land use. In GLOBE, we use an adaptation of the international system used by the United Nations which we call the Modified UNESCO Classification (MUC) system. See Tables LAND-P-3 and LAND-P-4.

Identification of the various land cover classes in an area can be done in a number of ways. In studying large areas, satellite data sets are common sources of images of land surface characteristics used to make land cover maps. However, simply examining an image without some specific knowledge of the area involved may reveal little about what the actual land cover is. The best and most accurate source of information on the kinds of land cover comes from visiting the site and conducting a detailed assessment of its characteristics on the ground. The data gathered by your students from such visits constitute an important source of information about the land cover within your 15 km x 15 km GLOBE Study Site. In particular, the detailed data acquired from 90 m x 90 m Land Cover Sample Sites will contribute to a better understanding of the *biomass*, the land cover, and the amount of photosynthesis taking place in your part of the world.

Natural vegetation is so important to the myriad processes and cycles of interest to Earth system scientists that you will be conducting several detailed measurements in some of the ground sites which are dominated by vegetation. These measurements are referred to as *biometry* and they quantify the size and extent of the plants in these sites. This is important information for a variety of reasons:

1. Although humans have extensively modified and replaced natural vegetation, most of the Earth's land surface is still covered by the naturally vegetated ecosystems which evolved in response to local geographical and climatic conditions. The type and nature of the vegetation present therefore tells us a great deal about other environmental variables such as rainfall or temperature.
2. Terrestrial vegetation is a major component of the large system we call Earth. Plants absorb and cycle nutrients - carbon dioxide, nitrogen, sulfur and phosphorus from the atmosphere and soil. They absorb water from the soil, incorporating it into their tissues, and *transpiring* some of it to the atmosphere. Plants also form the basic foundation of the food chains which support other life forms.

3. Vegetation can be a sensitive indicator of change in local or regional environments. Subtle changes in climate or other environmental factors may reveal themselves first as changes in the type or growth of local vegetation.
4. Human-induced changes in vegetation affect not only the plants themselves, but all the important cycles of nutrients and water in which vegetation plays so important a role. To understand the changes taking place in the Earth system, the human-induced and natural changes in land cover must be tracked.
5. Because of the importance of vegetation, the land-oriented satellite sensor (Thematic Mapper) you will use for mapping is designed specifically to identify and discriminate various kinds of vegetation. In addition, recent research has shown that satellite data are sensitive to the amount and health of many types of vegetation, but ground observations are needed to quantify and calibrate these relationships.

For all of these reasons, Earth system scientists are eager to have your maps, and your detailed biometric observations of naturally vegetated ground sites. Your data will tell us how important factors in the Earth system may be changing over time and how sensitive or resilient ecosystems are in the face of environmental change, and will improve our ability to interpret the satellite imagery we rely on to monitor large areas of the Earth's land surface.

Your field observations fill a major gap in scientists' ability to understand our planet because, even with your help, it is virtually impossible to visit the number of sites and collect all the data that we need. There is simply not enough time, money, or energy to get to enough sites. Therefore, the use of remotely sensed data (information collected from photography and satellite imagery) is critical to acquiring all the knowledge we need to understand the Earth as a system. Remotely sensed data can quickly and efficiently cover the entire Earth. As a GLOBE school you are given satellite imagery of a relatively large area compared to your school size. It would be very time-consuming and difficult for you to visit every area in your 15 km x 15 km GLOBE Study Site and yet one Landsat satellite Thematic Mapper image easily covers your area and 100 more like it. Using the tools that are described in this protocol you will generate a land cover map of your entire GLOBE Study Site by manual interpretation and by use of a computer program called MultiSpec. From these land cover maps, using the MUC classification scheme, you and your students will learn much about the area around your school.

Does producing this land cover map take the place of visits to sites on the ground? Absolutely not! The ground data collection is critical to effective use of the remotely sensed information. In order to be able to make the land cover map from the remotely sensed data, it is necessary to have visited some sites on the ground so that you can accurately identify certain sites on the satellite image. Without this ground data it would be impossible to make an effective land cover map from the satellite imagery.

The second use of your ground data is verification of land cover maps. A vital consideration for every scientist is the confidence that she or he can place in data collected by others or by automated systems. Often this confidence is based on some statistical measure, and such is the case in evaluating land cover maps generated from remotely sensed data. In order to have some confidence in a land cover map and make decisions based upon it, it is critical that the map be tested to see how good it is. This validation process is performed by comparing sample areas on the map with actual site visits on the ground. This comparison is then summarized in a table, called a difference or error matrix, which shows how well the land cover map represents what is really on the ground. Without ground data it would not be possible to generate land cover maps from remotely sensed data nor could we validate them once they were created.

GLOBE Student Data as Input to Models

Research scientists will incorporate GLOBE student data into models used in on-going research projects. The long-term goal of their research projects is to understand the primary biogeochemical cycles of Planet Earth. The primary cycles to be studied include those of carbon, sulfur, nitrogen and water. The overall strategy is to use numerical models to study how these cycles function, both in natural systems, where perturbations in the environment are produced primarily by climate variability, and in systems where disturbances have been induced by human activities. Among the GLOBE measurements used as inputs for such models are:

- Land cover class (MUC)
- Maximum/minimum air temperature throughout the growing season
- Precipitation throughout the growing season
- Tree circumference at a height of 1.35 meters and how it changes over time
- Soil moisture throughout the growing season

By collecting data using the *Land Cover/Biology Protocols*, you and your students will become partners in this type of Earth system science research. The essence of a partnership is that each of the participants brings unique strengths which make the collaboration stronger. Your contribution is the intimate knowledge you have, and can obtain, of your local area. The Earth system scientists place that knowledge in the larger context of their models and efforts to understand our whole planet. Only by working together can we hope to know both the details and the integrated picture of the Earth system.

Student Learning Goals

There are two overarching concepts for this investigation. The first is systems, as examined by the sample site and biometry protocols. The sub-concepts involved are productivity, boundaries, inputs, outputs, cycles (seasons, feedback loops). Some of the processes are representative sampling, indirect and direct measurements, classification (using generalizations and choices), and drawing conclusions based upon evidence.

The second overarching concept is models, and is particularly important for the mapping and accuracy assessment protocols. Sub-concepts are representations of reality, symbolic representation, scale, perspectives, habitat, land use changes, and habitat fragmentation. Some of our processes are mapping, modeling, and validation.

Why Scientists Use Models

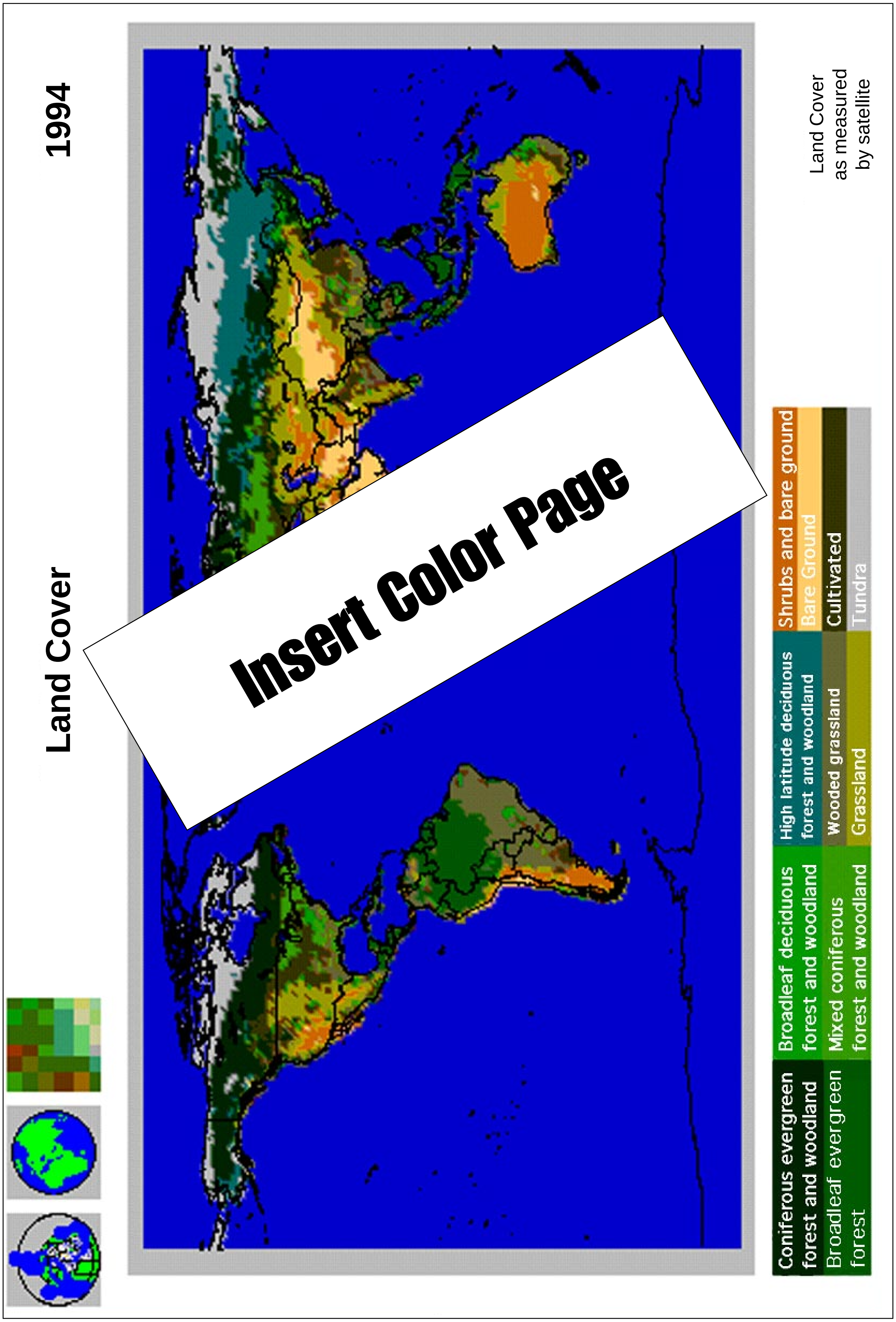
As children, we all played with toys. Toys are generally physical models which represent items that are important in the adult world and that are not available to children. Baby dolls, toy cars and trucks, stuffed animals, etc., are all examples of physical models that allowed us to use our imaginations to explore and better understand our childhood world. Conceptual or mathematical models are a tool used by scientists to explore and better understand processes or phenomena in the real world. There are several reasons why models are used.

One of the reasons is that models allow scientists to evaluate processes or phenomena that would be difficult to study in any other way. The study of the processes of photosynthesis and *evapotranspiration* is such an example. In both cases, the rate of each process is dependent on gas exchange at the stomates in leaves. Open stomates allow exchange of carbon dioxide (CO_2), oxygen (O_2) and water vapor, while closed stomates dramatically reduce such gas exchange. Measurement of small amounts of gas exchanged by a single leaf is possible using a device known as an i*nfrared gas analyzer*, but it is time consuming and only allows one leaf to be analyzed at a time. However, if light conditions are known (full sunlight causes stomates to open, while cloudy conditions lead to closed stomates in many plants), and the amount of recent rainfall (which governs the availability of water needed to open stomates) and maximum temperature (temperature influences the rate of diffusion of these gasses in or out of the open stomates) are known, a model can be developed which predicts gas exchange rates. If the amount of foliage is known, the photosynthetic rate and evapotranspiration rate for entire trees and/or forests can be modeled.

Another reason for using models is that in order to make a model which works well (the predicted results compare well with actual measured results) the developer of the model must really understand the process being modeled. Developing a model forces scientists to consider all of the input variables (such as CO_2, O_2 and water vapor, as well as temperature, available water, duration and intensity of sunlight, etc.) and the interrelationships among these variables. As a part of the process of developing a model, a more thorough understanding of the process being modeled results.

A third reason for using models relates to being able to modify the input parameters in order to predict realistic changes in output. This is an especially valuable aspect of using models when actual experimental manipulation of input variables is either impractical or impossible. Using the example of photosynthesis and evapotranspiration, a model allows scientists to study the effects of increasing atmospheric CO_2 and temperature on both photosynthetic activity (primary production) and return of water vapor (transpiration) to the atmosphere for forested sites. Such an experiment would be impractical to do in the field.

Figure LAND-I-1: Global Land Cover



Source: GLOBE Home Page

How to Perform Your Land Cover/Biology Investigation

Qualitative Land Cover Sample Site Protocol

Students locate, photograph, and determine the MUC class for 90 m x 90 m areas of homogeneous land cover.

Quantitative Land Cover Sample Site Protocol

Students locate and photograph 90 m x 90 m areas of forest, woodland, or grassland, take measurements of the properties of the vegetation, and determine the MUC class.

Biometry Protocol

Students measure properties of vegetation and identify species.

MUC System Protocol

Students use the MUC System to classify land cover

Manual Interpretation Land Cover Mapping Protocol

Students delineate different areas of land cover as seen on their TM image.

Unsupervised Clustering Land Cover Mapping Protocol

Students use MultiSpec to perform unsupervised clustering of their TM image and then assign MUC classes to every cluster to obtain a land cover map.

Accuracy Assessment Protocol

Students use observations of validation Land Cover Sample Sites to construct a difference/error matrix and determine the accuracy of their land cover maps.

How to Perform Your Land Cover/Biology Investigation

The goals of the Land Cover/Biology Investigation are threefold:

1. to take detailed measurements at selected sites within the entire GLOBE Study Site. These measurements are used by scientists to study vegetation growth and change and to verify maps made from remotely sensed data.
2. to make observations at many sub-areas within the entire study site. These observations are used by scientists, and can be used by you, to validate land cover maps generated from remotely sensed data.
3. to create a land cover map of your entire study area. This map will be used in learning more about your surroundings by making observations and measurements at selected sample locations. Upon competing this investigation, you will know a great deal about the environment surrounding your school and will be able to monitor change as it happens.

Study Sites for the Investigation

The Land Cover/Biology Investigation requires two different kinds of study sites. The first is called the GLOBE Study Site and is the 15 km x 15 km area, with your school near the center, for which satellite imagery is provided to you by GLOBE. By performing the protocols and learning activities associated with this investigation, you and your students will become intimately familiar with this part of our global environment. Together, you will create a land cover map of the entire area, make observations about many sub-areas, and take detailed measurements in some of these areas.

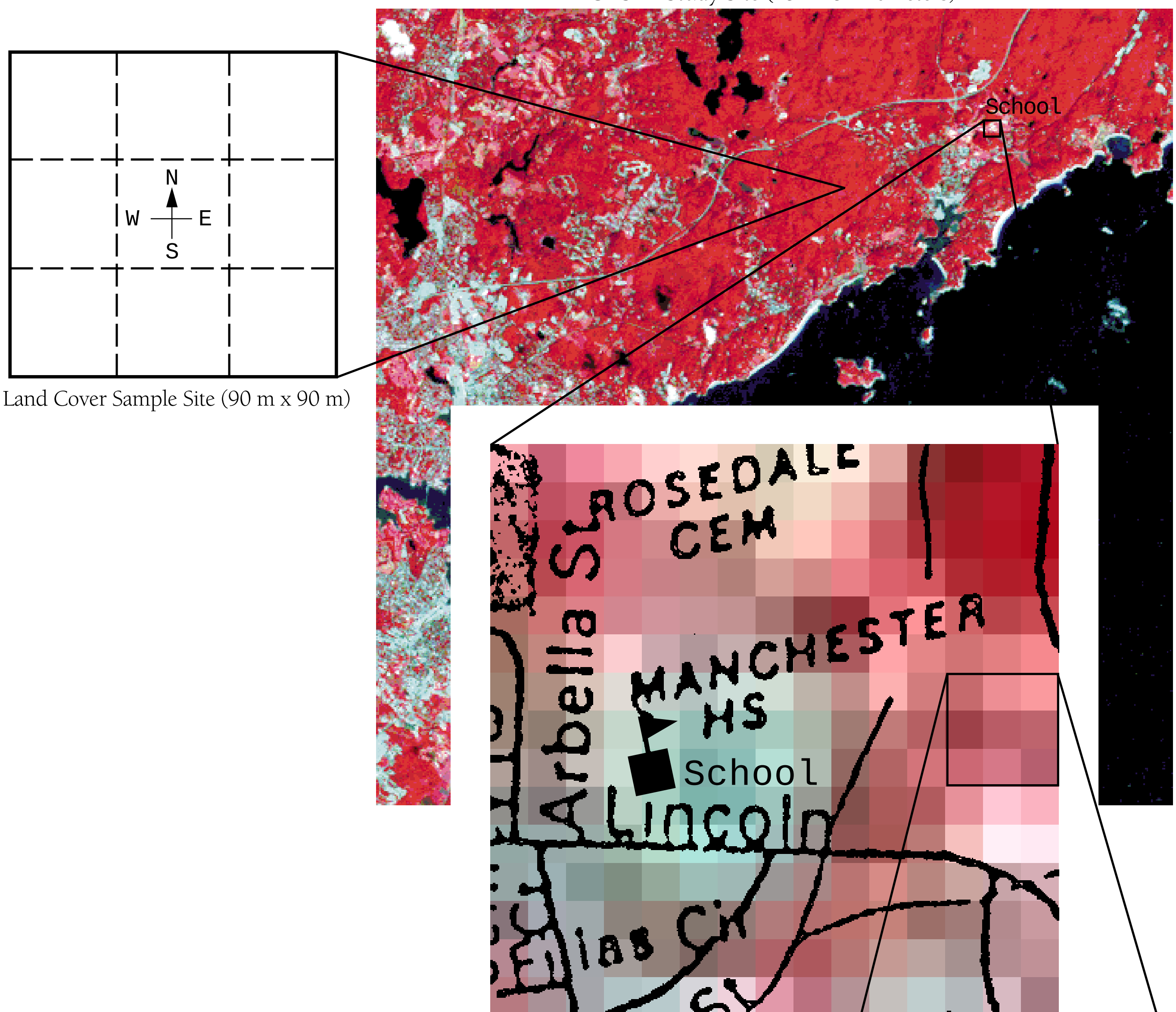
Within this GLOBE Study Site, it is important that you select appropriate ground sites (called Land Cover Sample Sites) for detailed measurements and observations. See Figure LAND-P-1. From an instructional standpoint, the goal of these Land Cover Sample Sites is to give your students a feel for the physical dimensions of *pixels* (picture elements) in the Landsat satellite Thematic Mapper images as well as providing a suitable and convenient site for class measurement activities within the GLOBE Study Site. For scientific purposes, a series of ground observations described later in this section need to be made in selected sample sites which are both representative of major types of land cover within your 15 km x 15 km study area, and large enough that they can be reliably located in satellite imagery.

Land Cover Sample Sites are areas of homogeneous land cover at least 90 m x 90 m in size. If the homogeneous area is larger than 90 m x 90 m, then the sample site is located toward the center of the area. See Figure LAND-P-3. An area 90 m x 90 m is necessary in order to accurately locate it on the ground and on the satellite imagery. This area is equivalent to 9 Landsat Thematic Mapper (TM) satellite pixels (a square of 3 pixels by 3 pixels). See the *Remote Sensing* section of the *Implementation Guide*.

There are two kinds of Land Cover Sample Sites - Qualitative and Quantitative. The latitude, longitude, and elevation of all Land Cover Sample Sites must be determined using a GPS (Global Positioning System) receiver, the land cover must be classified using the Modified UNESCO Classification (MUC) system, and the land cover must be documented in photographs taken from the middle of the site. The data for Qualitative Land Cover Sample Sites are easier to collect and require only these observations. Quantitative Land Cover Sample Sites require detailed measurements of the vegetation at the site and are only possible for certain land cover types. Qualitative and Quantitative Land Cover Sample Sites are visited only one time. However, within at least one Quantitative Land Cover Sample Site, each school should establish a permanent Biology Study Site. This site is used for obtaining long-term, periodic data related to vegetation growth. The Biology Study Site should be located in the center of a

Figure LAND-P-1: Land Cover Sites, Beverly, MA, USA as an example

GLOBE Study Site (15 x 15 kilometers)

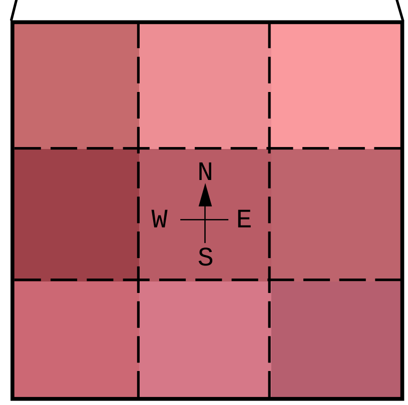


Land Cover Sample Site (90 m x 90 m)

(Approximately 450 x 450 meters)

Note: The "graininess" of the pixels in the 450 m x 450 m image is not real data - it is an artifact of reproduction. Each pixel is actually completely uniform as is shown in the enlargements.

A Biology Study Site should be located within a 90 m x 90 m Quantitative Land Cover Sample Site as shown at lower right. Additional Land Cover Sample Sites should be located in all major cover types within the GLOBE Study Site, as shown at top.



A Biology Study Site (30 m x 30 m) within a Quantitative Land Cover Sample Site (90 m x 90 m)

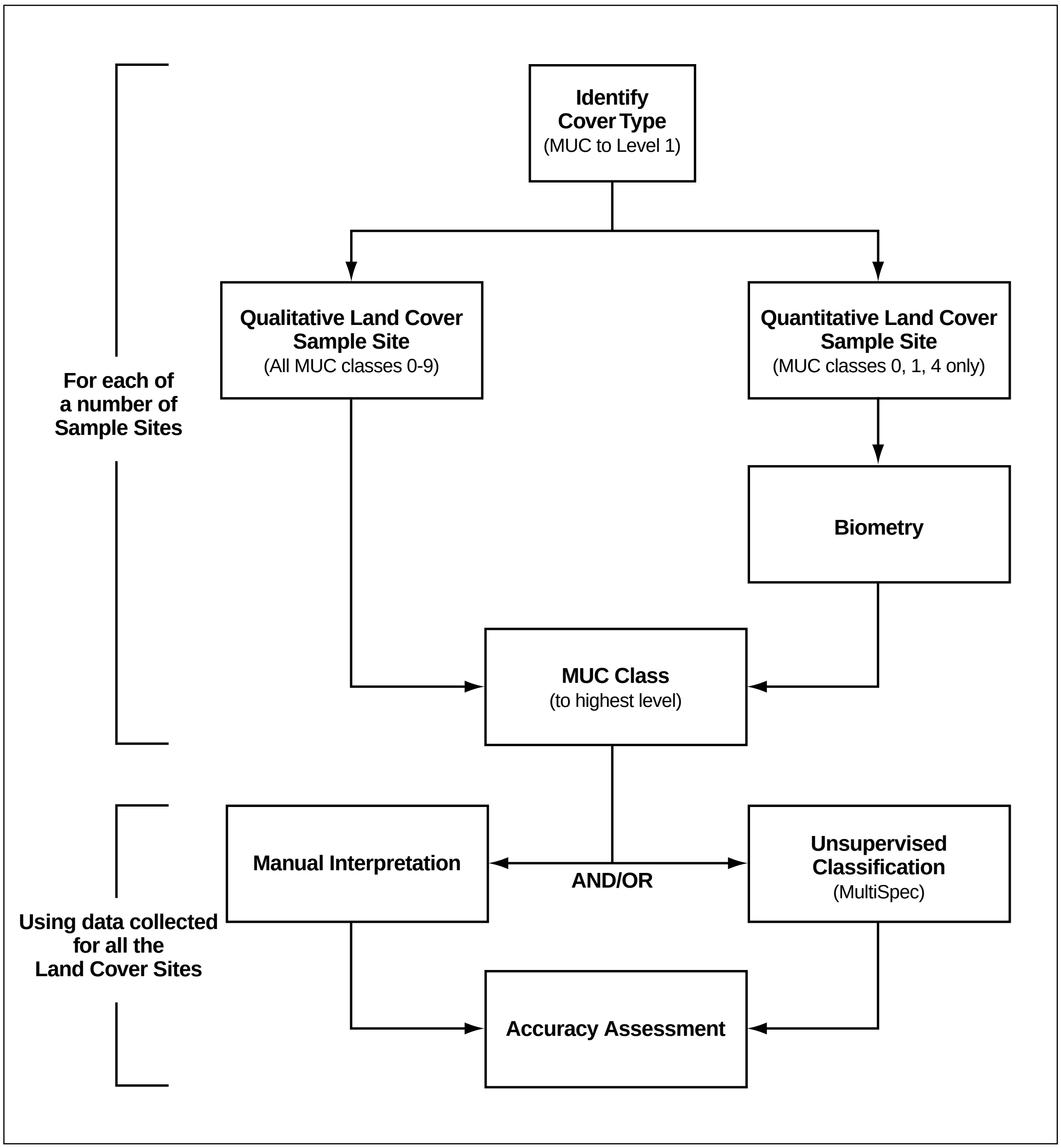
Quantitative Land Cover Sample Site. Only homogeneous areas of Forest, Woodland, or Herbaceous vegetation can be Quantitative Land Cover Sample Sites. You will learn more about this in the next section and in the *MUC System Protocol*.

The following flow diagram (Figure LAND-P-2) presents the steps to take to complete the Land Cover/Biology Investigation. The first step is to identify the general land cover type. All the other steps in this diagram correspond to protocols.

Identify the General Land Cover Type

The characterization of GLOBE Land Cover Sample Sites can only proceed within the context of a specific land cover classification system. The system used for GLOBE is the Modified UNESCO Classification system (MUC). This classification system is a tool for putting every possible land cover type on Earth into a unique land cover class. Each MUC class is a distinct type of land cover, with a name and an identification number, or MUC code.

Figure LAND-P-2: Flow Chart of Land Cover/Biology Investigation



About the MUC System

The GLOBE program uses MUC, an ecological classification system which follows international standards and ecological terminology for the identification of specific land cover classes. By using a standard international classification system, all the GLOBE data may be compiled into a single regional or global land cover data set. Thus ground data may be gathered and used to validate remotely sensed data following the same scientific protocols worldwide. This classification system enables GLOBE participants to accurately describe the land cover at any one point on Earth using the identical criteria as all other GLOBE participants.

There are two components of the MUC system. Part one is the outline of the classification system, containing the hierarchical list of labels for every class. Part two is the glossary, with rules and definitions. Before classifying any land cover type, it is crucial to *always* check the definition of the particular land cover class you believe is appropriate. Even if you think you know what a forest is, you should check the definition to confirm that your site is, in fact, a forest and not a woodland.

MUC has a hierarchical, or tree, structure, with ten level 1 classes. These classes are very general and easily identified. You must select one unique MUC class to identify a land cover type at each MUC level, beginning at level 1. Within each level 1 class there are two to six more detailed level 2 classes. Level 2 classes are still quite general and easily distinguished. Levels 3 and 4 are more specific communities or vegetative associations. The hierarchical structure of the MUC system simplifies the classification process. At each level your choices are restricted to only those classes which fall within the single class you have selected at the previous level. Thus while the whole MUC classification system has over 150 classes, at each step your choice is typically among only three to five land cover types.

In order to conduct the Land Cover/Biology Investigation, it is necessary first to identify the level 1 MUC class for each Land Cover Sample Site Each level 1 class is general and can be identified by visually estimating the percentage of the ground covered by the land cover present at the sample site. Table LAND-P-1 shows the 10 level 1 MUC classes. All MUC level 1 classes are determined by the percentage of the total sample area covered by the dominant land cover type.

Identifying MUC Level 1 Class

1. Select an area of homogeneous land cover as your Land Cover Sample Site.
2. Visually estimate the percent of the ground covered by the dominant land cover.
3. Review MUC level 1 class definitions to be sure students understand them.
4. Proceed with the steps of How to Classify Land Cover Sample Sites to MUC level 1 given in the *MUC System Protocol.*

Table LAND-P-1: Level 1 MUC Land Cover Classes

MUC Code	MUC Level 1 Classes	Coverage Required
0.	Forest	>40% Trees, 5 meters tall, crowns interlocking
1.	Woodland	>40% Trees, 5 meters tall, crowns not interlocking
2.	Shrubland	>40% Shrubs, 0.5 to 5 meters tall
3.	Dwarf Shrubland	>40% Shrubs, under 0.5 meters tall
4.	Herbaceous Vegetation	>60% herbaceous plants, grasses, and broadleafed plants (forbs)
5.	Barren	<40% vegetative cover
6.	Wetland	>40% vegetative cover, includes marshes, swamps, bogs
7.	Open Water	>60% open water
8.	Cultivated Land	>60% non-native cultivated species
9.	Urban	>40% urban land cover (buildings, paved surfaces)

Once you have established the level 1 MUC class of a Land Cover Sample Site, you are ready to proceed with one of the Land Cover Sample Site Protocols. If a Land Cover Sample Site is a forest or woodland or is covered by herbaceous vegetation (i.e. MUC level 1 land cover classes 0, 1, or 4), students may take the biometry measurements described in the Quantitative Land Cover Sample Site and *Biometry Protocols*. In other areas, GLOBE does not currently have protocols for biometry or other detailed quantitative assessments of the land cover. For these sites, students should take the measurements in the *Qualitative Land Cover Sample Site Protocol*. In some cases, you may decide to use a particular site as a qualitative sample site and not take biometry measurements even though the level 1 MUC class of the site would allow it to be quantitative sample site.

Establishing Different Types of Sites

In general, GLOBE schools only establish one of their Quantitative Land Cover Sample Sites as a permanent Biology Study Site, but establishing more sites is permissible. Over time, the goal is to establish one or more Land Cover Sample Sites in each of the major types of land cover identified within your 15 km x 15 km Globe Study Site. Start with the most common types of cover, and continue to add sample sites until you have located them in as many of the cover types as possible. When your school has the GPS instrument, measure and record the center point longitude, latitude, and elevation of all Land Cover Sample Sites you have identified up to that time.

Additional Land Cover Sample Sites are important for verifying the accuracy of land cover maps, which is a key scientific objective of GLOBE. It is recognized, however, that it will take time, perhaps several successive years, to accumulate a set of sample sites representative of each important type of cover within your Globe Study Site. You may want to assign a cover type to each of several classes, so that no two classes are working in the same type of cover and so as much data as possible are collected.

Qualitative and Quantitative Land Cover Sample Sites and Their Use in Land Cover Mapping

There are two types of land cover data collected in the GLOBE protocols — *qualitative* and *quantitative*. There are also two purposes for which you will use these land cover data: (1) help in labeling your land cover map (training), and (2) validating (or assessing the accuracy) of your classified land cover map (validation). Both are critical components to any mapping project using remotely sensed data and are analogous to the ways in which scientists and others will use your data.

Both training and validation data are collected for 90 m x 90 m sites, usually within your 15 km x 15 km GLOBE Study Site. These sites are called *Land Cover Sample Sites, and* must be within areas of homogeneous land cover. See Figure LAND-P-3. For this investigation, homogeneous land cover means that the entire site is representative of one of the specific land cover classes defined in the *MUC System Protocol.*

Figure LAND-P-3: Homogeneous Land Cover Site

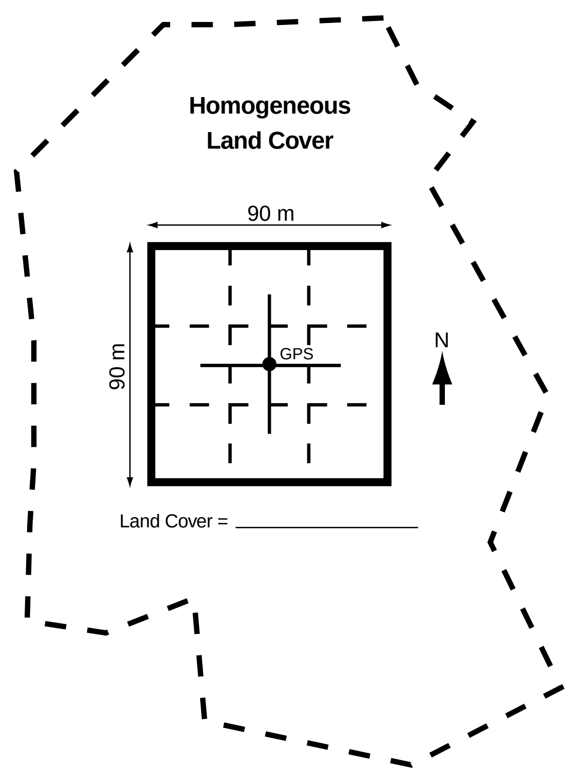


Table LAND-P-2: The Uses of Qualitative and Quantitative Data in Land Cover Mapping

Data Purpose	Data Type: Qualitative Land Cover Sample Sites	Data Type: Quantitative Land Cover Sample Sites
Training Data	Obtain the lay of the land during map development; assign land cover classes quickly	Gain a thorough understanding of the appearance of land cover types on ground and image
Validation Data	More easily obtain enough land cover sites for statistically valid map accuracy assessment	Best for map accuracy assessment; detailed information about forest, woodland and herbaceous vegetation sites Helps students and scientists understand appearance of cover types on both the ground and satellite images

The following definitions should be helpful in understanding the difference between the types of data collected and the data collection methods.

Training Data: Land cover data collected at Land Cover Sample Sites to help identify or label unknown clusters on the unsupervised classification of the TM image and/or to help in the manual interpretation of the TM image. These data can be collected using qualitative or quantitative data collection methods. Training data should *never* be used to assess the accuracy of the map because they have been used in the training process and you can not use the same data to train as well as validate your results.

Validation Data: Land cover data collected at Land Cover Sample Sites to assess the accuracy of the classified map created using manual interpretation or unsupervised classification of your local TM scene. These data can be collected using qualitative or quantitative data collection methods (quantitative is preferred whenever possible). Collect as many samples as possible for each land cover type present on the map because many samples are needed in the accuracy assessment process. These data should be used *only* for accuracy assessment.

Qualitative Data: In GLOBE, qualitative observation of land cover at a Sample Site requires only 3 components: (1) determining the latitude, longitude, and elevation of the site using GPS, (2) defining the MUC class using student observations of the site, and (3) taking photos in the four *cardinal* directions (i.e. north, south, east and west). This abbreviated set of land cover data can be used for *either* training or validation sites. Qualitative data are useful, especially when initially learning what land cover classes exist in your area and how to correlate what the land cover types look like on the TM image with what the same areas look like on the ground.

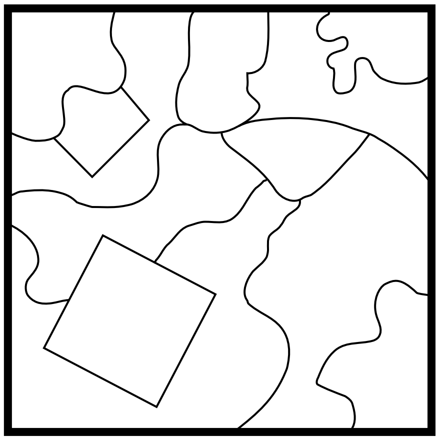
Quantitative Data: Quantitative land cover measurements are only possible for land cover classes for which GLOBE currently has Biometry Protocols (i.e., naturally occurring forest or woodland or herbaceous vegetation). In addition to the observations made for Qualitative Land Cover Sample Sites, at Quantitative Land Cover Sample Sites students take the measurements specified in the biometry protocol. These data are collected primarily for validation of maps generated from satellite imagery. The additional biometry measurements provide students and scientists with a more thorough understanding of forest, woodland, and herbaceous vegetation sites.

The Mapping and Accuracy Assessment Process

Figure LAND-L-4 illustrates the logical steps in producing a land cover map and assessing its accuracy. You are encouraged to begin collecting data on Land Cover Sample Sites even before you begin this mapping process. Student observations of individual sites are valuable because scientists can use them in their own land cover maps.

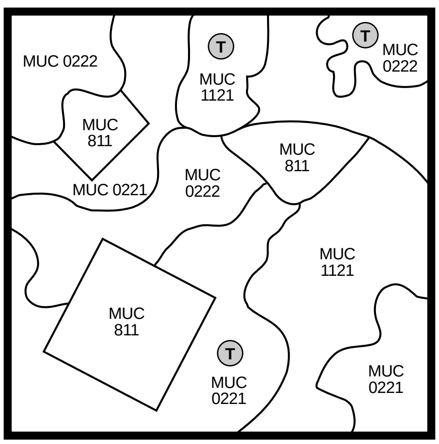
Figure LAND-P-4: Diagram of Accuracy Assessment Process

Step 1: Manual Interpretation or Unsupervised Clustering



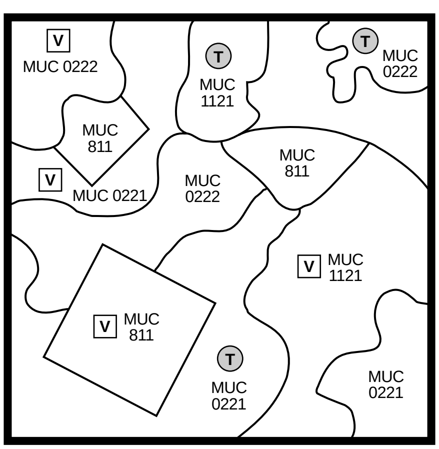
The TM image is divided into areas of similar land cover type manually or using MultiSpec.

Step 2: Assign MUC Classes to Areas or Clusters



For each area created by the manual interpretation or cluster created using MultiSpec, assign a MUC code using students' knowledge of the area and data collected from qualitative or quantitative training sample sites.

Step 3: Collect Validation Data



Once the land cover map is made, collect validation data at additional Land Cover Sample Sites to assess the accuracy of the classified map.

Over time, observe and measure as many validation sample sites as possible for each of the land cover types in your area.

T **Training Sample**

V **Validation Sample**

Figure LAND-P-4: Diagram of Accuracy Assessment Process (continued)

Step 4: Assess Map Accuracy

Validation Data

Map Classification	0222	0221	1121	811	**Row Total**
0222		1			1
0221		1			1
1121			1		1
821				1	1
Column Total	0	2	1	1	4

Using the difference/error matrix, compare the map classes to the validation sample classes determined from your observations and calculate the overall accuracy.

MUC Classes

0222 = Mainly deciduous forest with evergreen needle leaved trees

0221 = Mainly deciduous forest with evergreen broad leaved trees

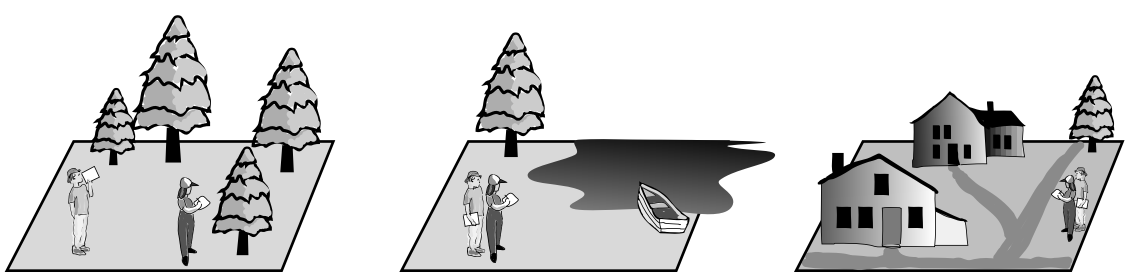
1121 = Mainly evergreen woodland with rounded crowns and needled leaves

811 = Pasture

Overall Accuracy = (3/4) * 100 = 75%

Figure LAND-P-5: Collect training and Validation Land Cover Samples

Collect Training and Validation Land Cover Samples



Special Considerations

Several time management, educational, and logistics issues should be considered in deciding how to present and undertake the various Land Cover/Biology protocols.

- Quantitative land cover information is far more useful and offers students a more complete view of the land cover assessment process.
- Measurement of a Quantitative Land Cover Sample Site involves careful biometry measurements, and students generally benefit from practicing these measurements before going to their study and sample sites.
- Virtually all GLOBE Study Sites contain developed areas of land cover, and in these areas only Qualitative Land Cover Sample Sites are possible.
- If a GPS receiver and a camera are available, observation of a Qualitative Land Cover Sample Site can be accomplished quickly.
- Data from multiple Land Cover Sample Sites are necessary in order to perform a manual interpretation of the entire GLOBE Study Site or to label the clusters that result from an unsupervised classification using MultiSpec. Even more validation sites must be collected to assess the accuracy of the land cover map generated either manually or using MultiSpec.
- Schools should collect as many sample sites as possible for each land cover type present on their land cover maps because many samples are needed in the accuracy assessment process; sites collected in different years and by different classes or even neighboring schools all can be used.
- The validation data must be independent of the data collected for training; it is not appropriate to use the same data for both training and validation because this will bias the results. Therefore, whatever data were collected and used for training must be set aside and only other samples used for validation.

Be sure to note the difference between naturally vegetated sites and cultivated sites. The Qualitative Land Cover Sample Sites can be collected for all land cover types. At present, the Quantitative Land Cover Sample Sites can only be collected for MUC classes 0, 1, and 4.

Qualitative Land Cover Sample Site Protocol

Purpose

To observe a Qualitative Land Cover Sample Site and collect the appropriate field data necessary for completing a land cover map from manual interpretation or unsupervised classification and for validating or assessing the accuracy of a land cover map

Overview

Qualitative field data are collected for a minimum of one Land Cover Sample Site for each land cover class in the GLOBE Study Site for which quantitative field data are not collected.

Time

20 - 45 minutes (excluding travel time)

Level

All

Frequency

Only need to collect data once for each Land Cover Sample Site

Multiple Land Cover Sample Sites are desired.

Key Concepts

Land cover map
Land cover classification
GPS
Field measurements

Skills

Locating a field plot (Land Cover Sample)
Using of GPS
Using field instrumentation (compass, tubular densiometer, clinometer)
Determining pace

Materials and Tools

Natural color, hard-copy TM image of your 15 km x 15 km GLOBE Study Site
Color infrared, hard-copy TM image of your 15 km x 15 km GLOBE Study Site
Compass
Tubular densiometer
Clinometer
GPS unit
Field form
Camera
MUC classification system and definitions

Preparation

None

Prerequisites

Leaf Classification Learning Activity

Introduction

The objective of collecting qualitative training and validation data is to familiarize the students with the entire GLOBE Study Site and identify the major land cover types present. These data can be collected rather quickly and efficiently, taking photos, using the GPS receiver to measure the location of the center of the site, and classifying the land cover using the MUC system. Qualitative training data can be used to label the unknown clusters resulting from unsupervised classification or as training areas for supervised classification. Data for additional Qualitative Land Cover Sample Sites can be used to determine the validity of your land cover map. It is anticipated that most schools will use this protocol many times to provide sufficient samples to perform a valid accuracy assessment of their land cover map. See the *Accuracy Assessment Protocol.*

How to Collect Qualitative Land Cover Sample Site Data

Step 1: Selecting and Locating Land Cover Sample Sites

- ❑ Select as your Land Cover Sample Site a 90 m x 90 m area of homogeneous land cover using either the TM image of your GLOBE Study Site or your observations in the field.
- ❑ Using the TM image for orientation, carefully locate and travel to the Land Cover Sample Site on the ground.
- ❑ Locate and carefully mark the center of the site with a temporary marker.

Step 2: GPS Location

- ❑ Obtain a Global Positioning System (GPS) unit. If you do not have the GPS unit when establishing a Land Cover Sample, make sure the center is clearly and durably marked and then come back and record the coordinates when you obtain a GPS unit.
- ❑ Perform the *GPS* or *Offset GPS Protocols* to determine the longitude, latitude, and elevation of the center of the Land Cover Sample Site. See the *GPS Investigation*.
- ❑ Record these data on the appropriate GPS Data Work Sheet and note the average latitude, longitude and elevation calculated on the Land Cover/Biology Investigation Field Data Work Sheet.

Step 3: Photos

- ❑ From the center of the site, take a photo in each of the four cardinal directions (N, S, E, W).
- ❑ Have two sets of prints developed or print out your digital photo.
- ❑ Label each photo with Land Cover Sample Site name and directional aspect.
- ❑ Retain one print or a copy of the digital photo for your school and send to GLOBE one print of each photo or a copy of the files for your digital photos.

Step 4: Determine MUC Class

- ❑ Perform the *MUC Protocol* to determine the MUC class. See helpful hints: *Pacing, Compass.*
- ❑ Record the MUC class on the Field Data Work Sheet.

Step 5: Report Data

- ❑ Review the data work sheets and record data in the school's permanent local data record.
- ❑ Report the data to GLOBE using the Qualitative Land Cover Sample Site Data Entry Sheet.
- ❑ Send copies of photos to the GLOBE Student Data Archive.

Helpful Hints: Pacing

Scientists, foresters, and others use pacing and compass bearings in conjunction with aerial photographs, maps or written instructions to find specific ground locations. As a convenience, many people who do field work determine how many of their paces it takes to travel a short set distance and use this to measure longer overall distances.

Pacing is specifically used in the MUC System and Qualitative and Quantitative Land Cover Sample Site Protocols to determine sampling points at which to take observations of ground cover and canopy cover. Methods for determining the length of one pace and the number of paces required to travel a set distance (called a *unit*) are discussed below.

Method for Determining the Length of One Pace

Step 1:
Lay out a 30 meter or longer measuring tape on a flat, open area (a parking lot, field, or hallway is good).

Step 2:
Remember that *one* pace is *two steps*. Starting with your toe at the 0 meter mark, pace off 10 paces, using a normal stride. It is important to use a normal, comfortable stride because of the wide variety of conditions encountered in the field.

Step 3:
Note the marking on the tape where your toe is on the tenth pace.

Step 4:
Divide that value by 10 to find the length of your pace.

Step 5:
Repeat this measurement three times and calculate the average to determine your average pace.

Example:

Repetition Number	Distance of 10 Paces	Distance of Single Pace
1	17.0 m	1.70 m
2	17.5 m	1.75 m
3	16.8 m	1.68 m
Average Pace = 1.71 meters per pace		

What To Do When in the Field

Pacing in the woods or over hilly terrain is quite different than pacing a flat distance in a school yard or parking area. Remember the following tips:

- When initially measuring your pace, be sure to walk using a comfortable stride. Resist the temptation to take exaggerated steps because your pace will naturally become shorter in the woods or over hilly terrain.
- When pacing up or down a hill, you are actually traveling a shorter horizontal distance than it seems, and you may also pace irregularly due to the terrain. Be aware of your paces and compensate by taking slightly shorter or longer steps as necessary.
- When large objects (boulders, large trees, etc.) are in the way, take a lateral side step, pace forward, then take another lateral side step back to your original compass bearing. If an observation is required while side-stepping and pacing around an obstacle, then estimate the reading from the side-stepped position.

If an object is too large to conveniently side step, leave a visible marker to find your place and walk all the way around. Start counting again at the marker on the other side of the object.

Method for Determining the Number of Paces Required to Travel One Unit

In the MUC, Qualitative, and Quantitative Protocols students are required to collect canopy and ground cover data for a distance of **1 unit = 21.2 meters** from the center of the Land Cover Sample Site. This distance was chosen because it is half the diagonal of a 30 m x 30 m pixel.

Step 1:
Measure a distance of 21.2 meters out on a flat, open area (a parking lot, field, or hallway is good).

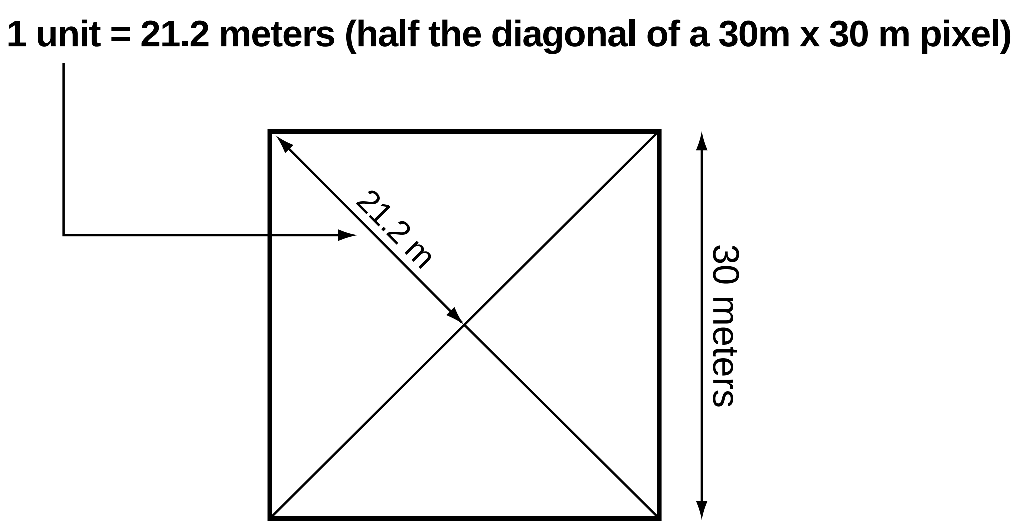
Step 2:
Remember that *one* pace is *two steps*. Starting with your toe at the 0 meter mark count the number of paces required to travel the entire distance using a normal stride.

Step 3:
Repeat this measurement three times and calculate the average to determine an average number of paces.

Step 4:
Round the number of paces to the nearest half pace.

Step 5:
Record each individual's pace so it can be referred to when collecting data at a land cover sample site.

Figure LAND-P-6: Pacing Example



Helpful Hints: Compass

The magnetic needle in a compass is attracted by the magnetism of the Earth, and that is why it always points North. However, there are really two North Poles on the Earth. One is the *True North Pole* which is located geographically at the top of the earth (at 90° North latitude); and the other is the *Magnetic North Pole*, an area of highly magnetic rock under central Canada.

Maps and directions are based on True North while the compass needle points to Magnetic North. Magnetic declination is the angle between True North and Magnetic North. Its size and direction depends on where you are on the Earth. It is necessary to determine the declination to take accurate compass bearings. Compasses either have a mechanism to set the angle of declination or a scale to determine declination.

Because compasses are attracted to metal objects they will give incorrect readings if the user is close to, or wearing, metal objects including watches, keys, etc.

Three Basic Parts of the Compass

1. The *magnetic needle* (See A in the Figure LAND-P-7) is attracted by the magnetic North Pole of the earth. The magnetic end (black) always points to magnetic north
2. The *graduated dial* (B) is used to set the desired bearing. The bearing is read in degrees at the sighting arrow (C) at the top of the compass. The dial is graduated in 2 degree increments from 0 to 360 degrees. The cardinal directions are at 0 (or 360), 90 degrees, 180 degrees and 270 degrees which correspond to North, East, South and West.
3. The *base plate* (D) has an orienting arrow (E) and a sighting arrow (C). Some models also have mirror sights attached. These components are used to line up the magnetic needle and point out the "line of travel".

Setting Compass Bearings

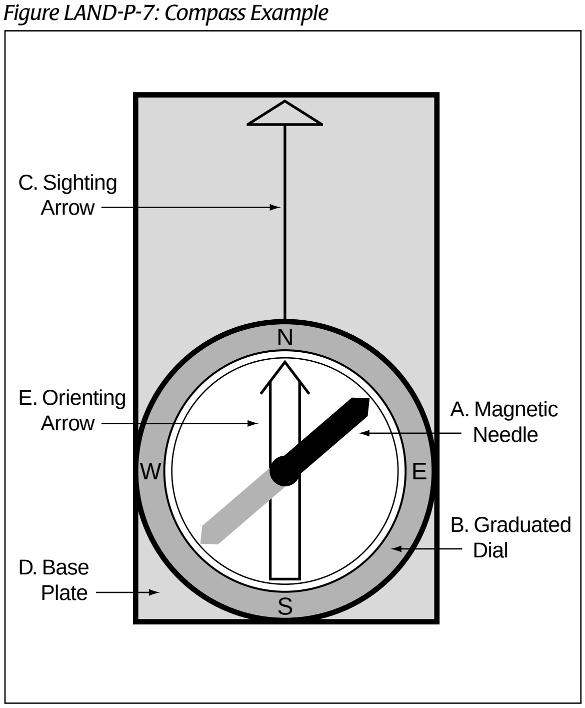
Step 1:
Set the dial (B) to the desired degree reading (the direction in which you want to travel) so that the correct compass bearing lines up with the sighting arrow (C).

Step 2:
While holding the compass level, turn your body until the red end of the magnetic needle (A) lines up with the red orienting arrow (E). "Put the red in the shed" is a useful saying to help students remember what to do. The red orienting arrow is considered the "shed."

Step 3:
Your direction or objective will now lie straight ahead in the direction you are holding the compass (the direction in which the sighting arrow points).

Be sure to choose an object ahead of you in line with your compass bearing and walk toward it. This allows you to walk without looking down at your compass. Every few paces stop and check that you are still traveling in the desired compass direction.

Figure LAND-P-7: Compass Example



Quantitative Land Cover Sample Site Protocol

Purpose

To measure Quantitative Land Cover Sample Sites and to collect the appropriate field data necessary for completing a land cover map made using either manual or unsupervised computer methods and for validating or assessing the accuracy of the land cover map

Overview

Quantitative field data is collected for a minimum of one Land Cover Sample.

Time

1-2 hours (excluding travel time)

Level

All

Frequency

Only collect data once for each Land Cover Sample Site.

Multiple Land Cover Sample Sites are desired. Over time, try to perform this protocol at least once for each major type of land cover within your GLOBE Study Site that is in MUC level 1 class 0, 1, or 4.

Key Concepts

Land cover map
Land cover classification
GPS
Field measurements
Biometry

Skills

Locating a field plot (Land Cover Sample)
Using of GPS
Using a compass, tubular densiometer, and clinometer
Determining pace

Materials and Tools

Natural color, hard-copy TM image of your 15 km x 15 km GLOBE Study Site
False-color infrared, hard-copy TM image of your 15 km x 15 km GLOBE Study Site
Compass
Tubular densiometer
Clinometer
Tape measure
GPS unit
Land Cover/Biology Field Data Work Sheet
Camera
MUC classification system and definitions

Preparation

None

Prerequisites

Leaf Classification Learning Activity

Introduction

Quantitative training and validation data provides the most detailed ground reference data possible. These data are used in quantitatively assessing the accuracy of remotely sensed maps. Every school is expected to collect data from at least one Quantitative Land Cover Sample Site, but each school is encouraged to collect as many Quantitative Land Cover Samples as they can.

It is critical to scientists to have as much validation data as possible. It is also important to have validation data in every land cover class in the GLOBE study site. Obviously, this data collection should continue through time and can result in a large and very valuable database of validation sites.

Steps for Quantitative Data Collection

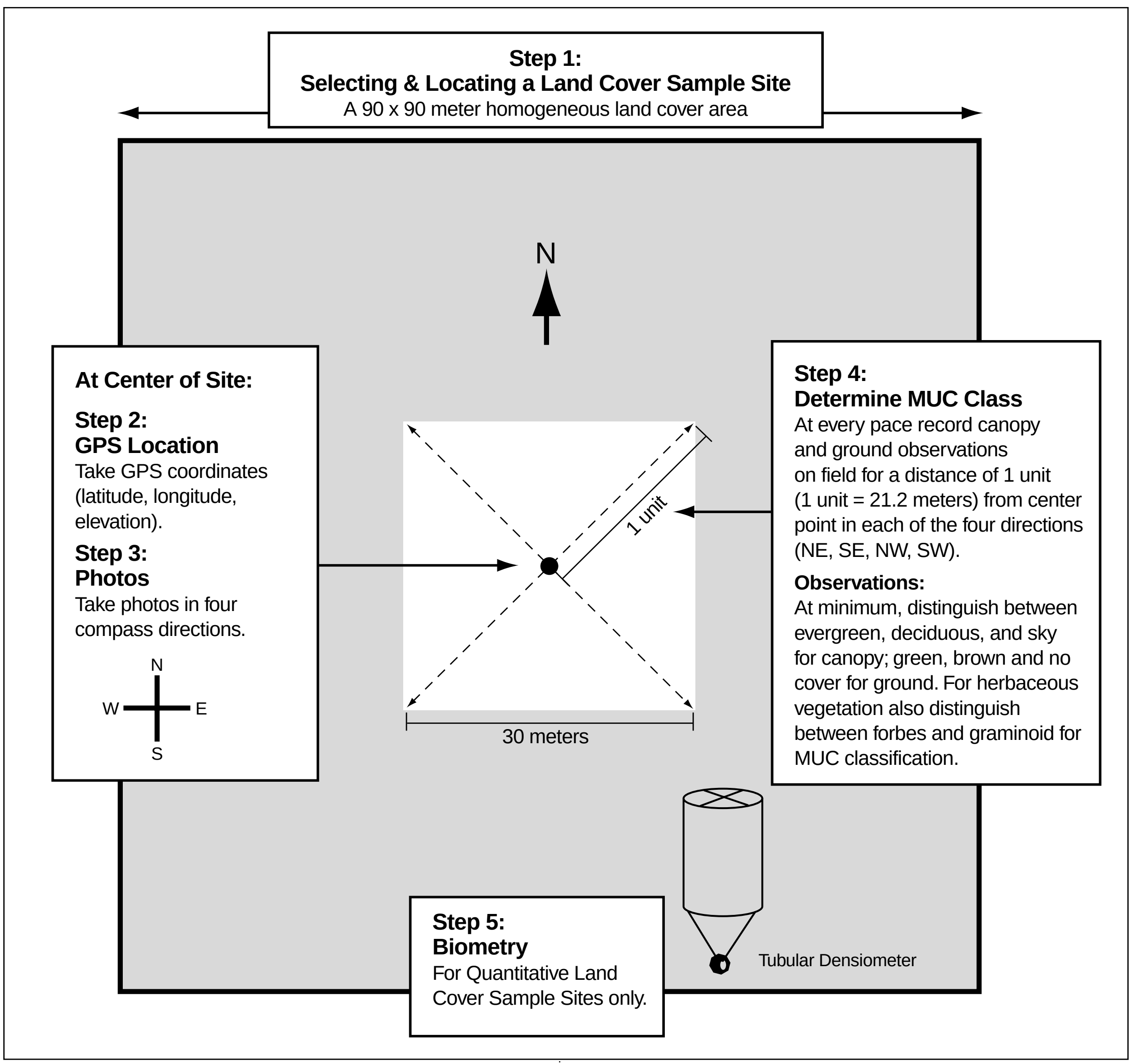
Step 1: Selecting and Locating a Quantitative Land Cover Sample Site

- ❑ Select a 90 m x 90 m area of homogeneous land cover using either the TM image of your GLOBE Study Site or your observations in the field.
- ❑ Using the TM image for orientation, locate and travel to the Land Cover Sample Site.
- ❑ Carefully mark the center of the site with a temporary marker.

Step 2: GPS Location

- ❑ Obtain a Global Positioning System (GPS) unit. If you do not have the GPS unit when establishing a Land Cover Sample, make sure the center is clearly marked and then come back and record coordinates when you obtain the GPS unit.
- ❑ At the center of the Land Cover Sample Site, record the GPS coordinates: longitude, latitude, and elevation. Refer to the *GPS Investigation*.
- ❑ Record on Land Cover/Biology Investigation Field Data Work Sheet.

Figure LAND-P-8: A Typical Quantitative Land Cover Sample Site



Step 3: Photos

- ❑ From the center of the Land Cover Sample, take a photo in each of the four cardinal directions (N, E, S, W).
- ❑ Have two sets of prints made, one for your school and one for GLOBE.
- ❑ Label each photo with Land Cover Sample Site name and directional aspect.

Step 4: Determine MUC Class

- ❑ Determine the land cover class following the MUC System Protocol.
- ❑ Record the MUC Class on Land Cover/ Biology Investigation Field Data Work Sheet.

Step 5: Biometry

- ❑ If the site is a forest or woodland (i.e. MUC classes 0 or 1), follow forest biometry protocols (height, circumference, dominant and sub-dominant species identification, crown closure, ground cover).
- ❑ If the site is covered by herbaceous vegetation (MUC class 4), follow the grassland biometry protocols.

Step 6: Report Data

- ❑ Review the data work sheets and record data in the school's permanent local data record.
- ❑ Report the data to GLOBE using the Quantitative Land Cover Sample Site Data Entry Sheet.
- ❑ Send copies of photos to the GLOBE Student Data Archive.

Biometry Protocol

Purpose

To quantify and record the land cover in order to determine the specific characteristics of a Quantitative Land Cover Sample Site

To provide GLOBE scientists and others with necessary land cover data

Overview

Students lay out a 30 m x 30 m area within a Quantitative Land Cover Sample Site. At these sites, students observe and record ground cover and canopy cover, identify dominant and co-dominant vegetation species, measure either tree height and circumference or the biomass of the herbaceous ground cover. They designate one of these sites as their Biology Study Site, where they will perform this protocol once or twice each year.

Time

One-half to one full day for each visit

Level

All

Frequency

One to two times per year for your Biology Study Site

One time only for all other Quantitative Land Cover Sample Sites

Key Concepts

- Relation of the pixel size of an image to a site on the ground
- Canopy Cover
- Ground Cover
- Tree Height and Circumference
- *Biomass* of herbaceous vegetation
- Dominant and *Co-Dominant* Species
- Land Cover Classification

Skills

- *Using* a clinometer and densiometer.
- *Using* compass directions
- *Making* ground measurements
- *Identifying* vegetation types and tree species
- *Using* a dichotomous key
- *Measuring* pace

Materials and Tools

- Color printed copies of your local 512 x 512 pixel Landsat Thematic Mapper scene in visible (3, 2, 1) and NIR (4, 3, 2)
- Local road or topographic maps (optional)
- Compass
- 50 m Tape measure
- Marking stakes, flags, or other permanent site markers
- GPS Unit
- Still Camera
- Tubular densiometer (4 cm diameter by 7.5 cm long tube, string, metal nut or washer, tape)
- Dichotomous keys and/or other local species guides
- Clinometer (Clinometer Sheet, cardboard, drinking straw, metal nut or washer)
- Table of Tangents
- Flexible tape measure
- Small bean bag
- Grass clippers or strong scissors
- Small brown paper bags
- Drying oven
- Balance or scale, accurate to 0.1 g
- Land Cover/Biology Investigation Field Data Work Sheet

Preparation

Select site(s)

Practice measurement techniques

Prerequisites

Site Seeing Learning Activity

Introduction

The *Quantitative Land Cover Sample Site Protocol* shows you how to establish Quantitative Land Cover Sample Sites and outlines the steps for collecting data on them. This protocol details the procedures for performing *biometry* measurements at all quantitative sites. This protocol can only be performed on sites with MUC level 1 class 0 (Closed Forest), 1 (Woodland), or 4 (Herbaceous Vegetation). You establish one of these quantitative sites as your Biology Study Site.

How to Lay-out a 30 m by 30 m Area for Biometry Measurements

Special Considerations for Biology Study Sites

Note: If you have already followed an earlier version of this protocol and have established a Biology Study Site, continue to use your current site for repetitive measurement following the later sections of this protocol.

The only difference between your Biology Study Site and the central 30 m x 30 m areas of other Quantitative Land Cover Sample Sites is that biometry measurements are repeated periodically at the study site while at sample sites observations are made just once. After identifying the dominant and co-dominant vegetation types, you will perform a series of biometry measurements over time.

Since your Biology Study Site is permanent, you need to mark the 30 m x 30 m center area where you perform all your measurements with permanent stakes, flags, or other markers. To mark this 30 m x 30 m area:

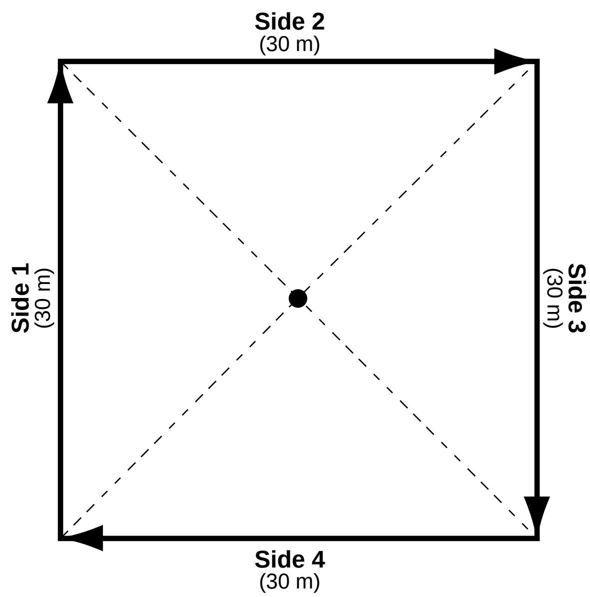
Step 1: Establish Your Biology Study Site

- ❑ Follow Steps 1 through 4 of the Quantitative Land Cover Sample Site Protocol. Make sure this site is a MUC level 1 class 0, 1, or 4 area.

Step 2: Establish and Mark Your 30 m x 30 m Biology Study Area

- ❑ Place a marker where you want one corner of your 30 m x 30 m square to be.
- ❑ Use your compass and measuring tape to move 30 meters in a *cardinal* direction (North, South, East, or West). Place a second marker at the end of this transect. This forms side one.
- ❑ From the second marker, move 30 meters perpendicular to side one. Place a third marker at the end of this transect. This forms side two.
- ❑ From the third marker, move 30 meters perpendicular to side two and parallel to side one. Place a fourth marker at the end of this transect. This forms side three.
- ❑ From the fourth marker, move 30 meters toward your original marker. If this transect ends within 2 to 3 meters of the original marker, you are successful. If you are farther off the mark, check your compass headings for each side, check the length of each side, and try again.
- ❑ Establish the center of your square by pacing the diagonal transects of the square and placing a marker where the two paths intersect. You may use string to make these diagonals.

Figure LAND-P-9: Biology Study Site Set-up



Making Biometry Measurements

Depending on the types of vegetation at your site, you and your students will make biometry measurements on canopy cover, ground cover, tree height and circumference, and/or grass biomass.

When to Make Biometry Measurements

At your Biology Study Site: make biometry measurements twice each year—once during peak growing season and once during the least active season. If you have no temperature or rainfall-dependent seasonality in your region, take measurements only once a year.

At all other Quantitative Land Cover Sample Sites: perform biometry measurements just once, as close to the peak of the growing season as possible.

How to Make Canopy Cover and Ground Cover Measurements

Step 1: Make a Densiometer

- ❑ Take a tube approximately 4 cm in diameter and 7.5 cm long. Attach two strings at perpendicular angles across the diameter of one end to form a crosshair.

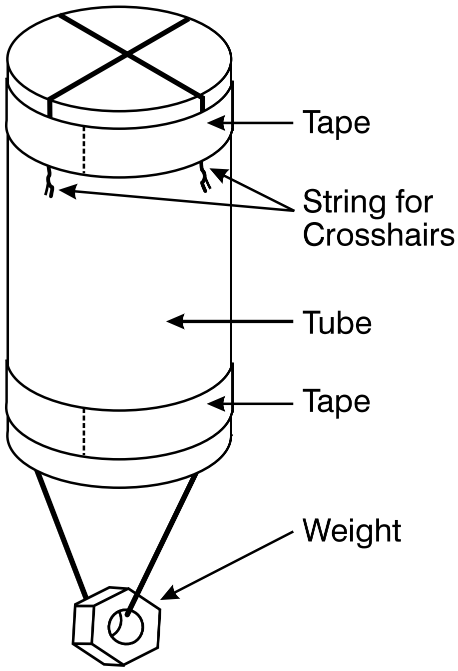


Figure LAND-P-10: Homemade Densiometer

- ❑ Attach an 18 cm piece of string with a metal nut or washer hanging loosely from it across the diameter of the other end of the tube. You have made a densiometer.

Step 2: Tally Canopy Cover and Ground Cover

- ❑ One or more pairs of students pace the two diagonals of the 30 m x 30 m square.
- ❑ After every pace, one student looks up at the canopy through the densiometer, making sure the metal nut/washer is directly below the intersection of the crosshairs at the top of the tube.

  Note: If it takes smaller students more than forty paces to complete a diagonal, they may take measurements at every other pace.
- ❑ If the student sees vegetation, twigs, or branches touching the crosshair intersection, the other student records a " + " in the proper space on the Dominant/Co-Dominant Vegetation Field Data Work Sheet. If no vegetation, twigs, or branches touch the crosshair intersection (i.e. the student sees the sky above the intersection of the crosshairs), the student records a " - ". The students should end up with a series of +'s and -'s.
- ❑ Now, the student looks down.
- ❑ If vegetation is underfoot or touches the foot or leg below the knee, the other student records a "G" if the vegetation is green, a "B" if the vegetation is brown, or if no vegetation touches the student underfoot or below the knee (i.e. the ground is bare), the other student records a " – ".

  For more accurate readings, other pairs of students should repeat these measurements.

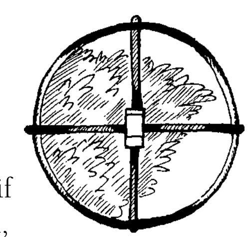
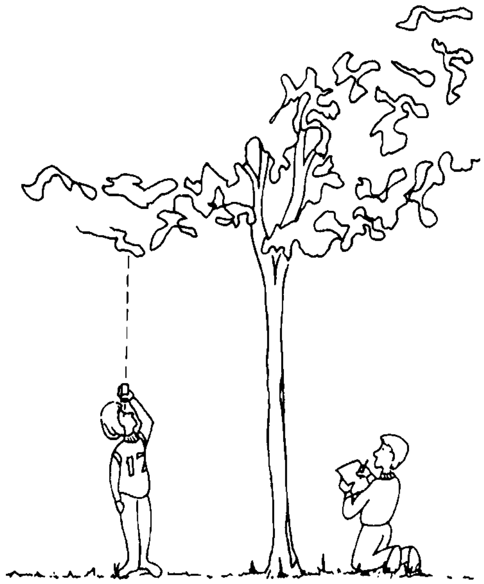


Figure LAND-P-11: Example using a homemade densiometer



Step 3: Report Findings for Canopy Cover and Ground Cover

- ❑ Report the number of +'s and -'s for canopy cover and the number of G's, B's, and -'s for ground cover to the GLOBE Student Data Server along with other biometry data.

  Note: If observations were repeated by different teams of students, choose only one team's set of data to report to GLOBE.

Step 4: Calculate Percentages of Canopy Cover and Ground Cover

- ❑ Calculate canopy cover percentage: Add up all +'s and divide by the sum of the +'s plus -'s. Multiply by 100 to convert this fraction to a percentage.
- ❑ Calculate green ground cover percentage: add up the G's and divide by the sum of the G's, B's, and -'s. Multiply by 100 to convert this fraction to a percentage.
- ❑ Calculate brown ground cover percentage: add up the B's and divide by the sum of the G's, B's, and -'s. Multiply by 100.
- ❑ Add the green ground cover and brown ground cover percentages together to obtain a total ground cover percentage.

How To Identify Dominant and Co-Dominant Vegetation

Having established your site(s), you have a general idea of what types of vegetation grow there. You and your students will now identify the most common (dominant) and second most common (co-dominant) vegetation types on your Biology Study Site or other Quantitative Land Cover Sample Sites. You may need this information to help you identify the MUC classification of your site using the *MUC Classification Protocol*. GLOBE scientists also need this information to study the growth of different kinds of vegetation. For Closed Forest and Woodland sites (MUC level 1 classes 0 and 1) we ask you to identify the scientific names (genus and species) of the two types of trees that have the most canopy coverage. For herbaceous sites (MUC level 1 class 4), identify the plant(s) that cover the most ground as *graminoid* (grass), or *forb* (broad-leaved). Please see the MUC Glossary in the *Appendix* for definitions of these terms.

Step 1: Identify Vegetation Types

- ❑ Repeat the canopy cover and ground cover measurements given above but this time the student identifies each tree species that touches the crosshair. The student also looks at the ground and identifies any vegetation type underfoot or touching her foot or leg. The other student records the types on the Dominant/Co-Dominant Vegetation Field Data Work Sheet.

Note: If you cannot identify the genus and species of a tree in the field, record the common tree name, if known. If the common name is not known, invent names and describe the tree well so that you can accurately identify it later.

Step 2: Calculate Which Vegetation Types Are Dominant and Which Are Co-Dominant

- ❑ Tabulate your results.
- ❑ If tree canopy cover is 40% or greater and the canopy is above 5 m in height, then your site is Forest or Woodland (MUC level 1 classes 0 or 1). The *dominant* vegetation is the tree species seen the most times through the densiometer. The *co-dominant* vegetation is the tree species

seen the second-most times. If your site is forest or woodland, identify the tree species using dichotomous keys or by consulting local experts. See Helpful Hint: How to Use Dichotomous Keys. Then, proceed to How to Measure Tree Height and Circumference.

- ❑ If tree canopy cover is less than 40%, and your ground cover is more than 60%, then your site is dominated by Herbaceous Vegetation (MUC level 1, class 4). The *dominant* vegetation is the plant seen the most times as part of the ground cover. The *co-dominant* vegetation is the plant seen the second-most times either on the ground or in the canopy. If your site is herbaceous vegetation, identify whether the land covers are *graminoid* (grasses) or *forb* (broad-leafed) using the definitions in the *Appendix*. If the herbaceous land cover is graminoid, proceed to How to Measure Grass Biomass. If the vegetation is broad-leaved, do not perform any further measurements or observations.

Step 3: Record Your Findings

- ❑ If your site is Forest or Woodland, enter the first four letters of the genus and species for both the dominant and co-dominant tree species in the proper space on your Dominant/Co-Dominant Vegetation Field Data Work Sheet.
- ❑ If your site is Herbaceous Vegetation, enter either "GRAM," for grass (graminoid), or "FORB" for other, broad-leaved vegetation, in the proper space on your Data Work Sheet.

Note: If the vegetation on your site is diverse, it may be difficult to identify the dominant and co-dominant vegetation. If two types are not clearly dominant and co-dominant, describe the vegetation types well in the Notes section of your Dominant/Co-Dominant Vegetation Field Data Work Sheet. Enter "mixed" on the *Dominant/Co-Dominant* line.

Examples

To give you a better sense of how this activity works, here are two examples of what might happen:

Example 1: You perform your canopy cover and ground cover measurements, recording the number of times you saw vegetation through your densiometer and the number of times you saw sky. Each time you see canopy vegetation through your densiometer, you also record and tally the tree species. You then calculate a canopy cover of 70% and note that the crowns of trees are touching each other. This means you classify your site as a *forest* (MUC level 1 class 0). The dominant tree species is the species with the most tallies. The co-dominant species is the species with the second most tallies.

Example 2: After you perform your canopy and ground cover measurements, you calculate that the canopy cover is 20% and composed of a single species of pine tree. Your ground cover is 90%, and is composed of 80% grass and 10% forb. This means you classify your site as *herbaceous vegetation* (MUC level 1 class 4). The dominant vegetation is grass ("GRAM" on the Data Work Sheet). Since 20% of the site is pine tree and only 10% of the site is forb, your co-dominant vegetation is the pine tree species.

Helpful Hints: How to Use Dichotomous Keys

The word *dichotomous* comes from the Greek words *dikha*, "in two," and *temnein*, "to cut." Thus, it's meaning: "division into two contradictory parts." A *key* is a table glossary, or cipher, for decoding or interpreting. A *dichotomous key* is a branching decoder, which forks into two approximately equal and contradictory divisions that lead to only one correct outcome. It is like a mouse maze. For the mouse to escape, it must make successive choices between two directions, one correct and one incorrect. The mouse will get out only after making all the correct choices.

To use a dichotomous key we, too, must choose correctly between two options in a series of contradictory options. We use our five senses (sight, hearing, touch, taste, and smell) to determine the correct choices. Here is a simple example of how we might choose what type of shoe we are wearing.

Assume you are wearing a pair of canvas running shoes. The first choice in the key asks if the shoes are made of leather or canvas. Since they are made of canvas, not leather, you follow the "path" to "CANVAS." Here you are asked if your shoes have lightweight soles and are low-cut or if they have heavy soles and are high-cut. Yours are lightweight and low-cut, so you have identified them as canvas running shoes.

Note that *all* dichotomous keys have inherent limitations. In this example, only six types of shoes are included. Even very extensive and technical keys omit some possible choices. This is especially true of exotic vegetation species that have been introduced into an area. Many dichotomous keys only include native species. If the plants you are trying to identify aren't native or your dichotomous key isn't complete enough, you may need to seek expert help.

A second limitation of many dichotomous keys is their use of imprecise terminology (e.g. "low-cut," "lightweight," etc.). Sometimes it is not clear what the authors of the key mean by these terms. The best keys are those that use objective, measurement-based characteristics rather than subjective options.

To help you identify species or find a local dichotomous key, consult foresters, local experts, university research scientists, etc. Your GLOBE Country Coordinator may also have useful information.

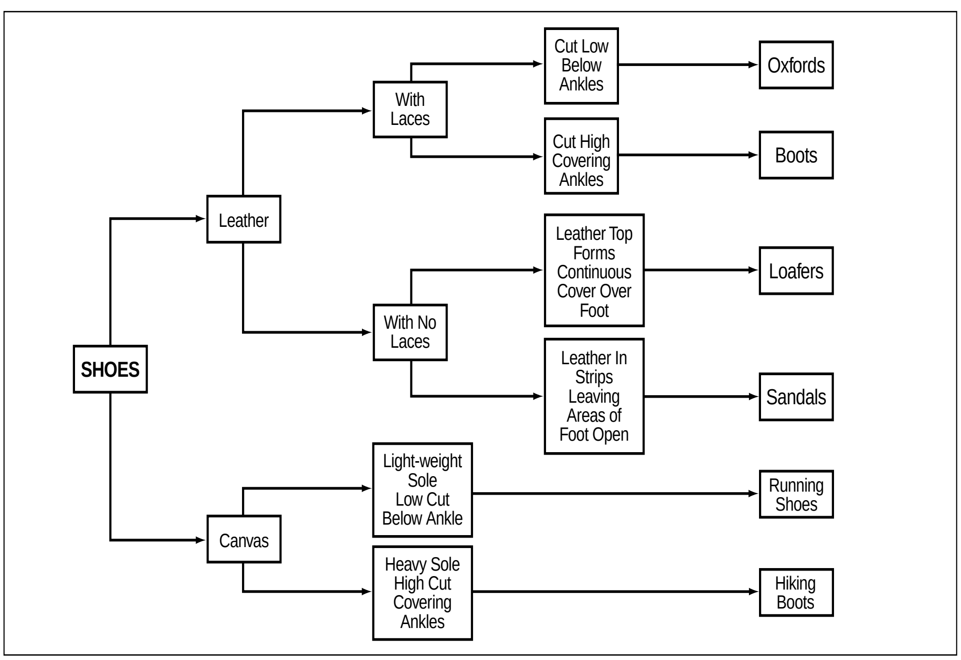


Figure LAND-P-12: Using a Dichotomous Key

How to Measure Tree Height and Circumference

How to Choose Which Trees to Measure

1. If the dominant species on your site is a tree, select five specimens of the tree. Include the largest tree, the smallest tree that still reaches the canopy, and three intermediate trees. Mark the trees for future reference.
2. If you have a co-dominant tree species, repeat the process. If there are fewer than five co-dominant species trees, include other tree species to make a total of five. Mark the trees for future reference.

How To Measure Tree Height Using a Clinometer

A clinometer measures angles to determine the heights of objects without directly measuring them. It is a simplified version of the *quadrant* (a medieval measuring instrument), and the *sextant*, an instrument used to locate the positions of ships. Like these instruments, the clinometer has an arc with graduated degree markings that go from 0 to 90 degrees. See Figure LAND-P-13. When you site an object through the clinometer's drinking straw, you can read the number of degrees of angle BVW by noting where the string touches the arc. Angle BVW is equal to angle BAC, which is the angle of elevation of the clinometer. If you know both the angle of elevation and your distance away from an object, you can calculate the height of that object using a simple equation.

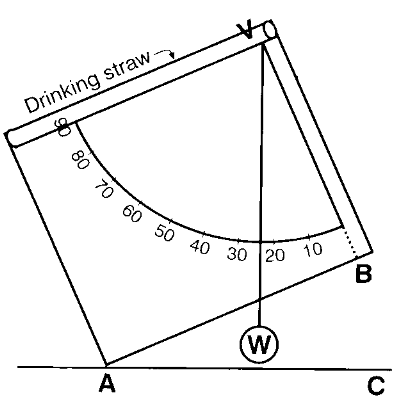


Figure LAND-P-13: Homemade Clinometer

Modified from Bennett, A. and Nelson, L. (1961) Mathematics an Activity Approach. Allyn & Bacon: Boston.

Step 1: Make a Clinometer

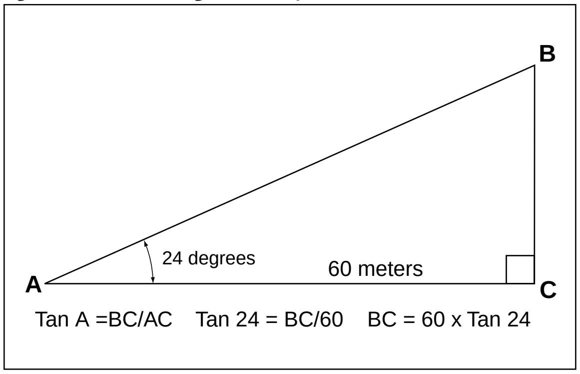
- ❑ Glue a copy of the Clinometer Sheet in the Appendix onto a same-size piece of stiff cardboard.
- ❑ Punch a hole through the marked circle on the sheet and tie one end of a 15 cm piece of string through it.
- ❑ Tie a metal nut or washer to the other end of the string.
- ❑ Tape a drinking straw along the designated line on the sheet, to use as a site.

Step 2: Measure and Record the Distances and Angles Needed to Determine Tree Height

- ❑ At one of your selected trees, move a predetermined distance away from the base of the tree and record the distance. This is your line AC. See Figure LAND-P-14. For the most accurate results you should adjust your distance away from the base of the tree so that Angle BVW is between 30 degrees and 60 degrees.
- ❑ Measure and record the height of your eye above the ground.
- ❑ Site the top of the tree through the drinking straw on the clinometer.
- ❑ Record the number of degrees in angle BVW on the clinometer; this tells you the number of degrees in angle BAC.

In the example (Figure LAND-P-15), a student stands 60m away from the base of a tree sites the top of the tree through his clinometer. His eye is 1.5 meters above ground. He reads an angle of 24 degrees on his clinometer (figures are not drawn to scale).

Figure LAND-P-14: Trigometric Equation



Step 3: Organize Your Data in a Drawing

Refer to Figure LAND-P-14 to draw and label a triangle that represents all the information you have accumulated.

Step 4: Calculate Tree Height

- ❑ Use your Table of Tangents in the Appendix and the following equation to solve for the height of BC:

  TAN<A = BC/AC

The above student solved his equation like this:
TAN 24 = BC/60. Therefore,

BC = 60 (TAN 24). Therefore,

BC = 60(.45) = **27m.**

- ❑ Add the height of BC to the height of the clinometer from the ground (your eye level) to get the total height of the tree. In the above example, the height of the tree is 27m + 1.5m = **28.5m.**

Note: For younger students, if the angle BVW is 45 degrees, the distance from the tree will equal the height of the tree above the student's eye level and this can be illustrated for students by drawing an isosceles right triangle without any additional explanation of the mathematics involved.

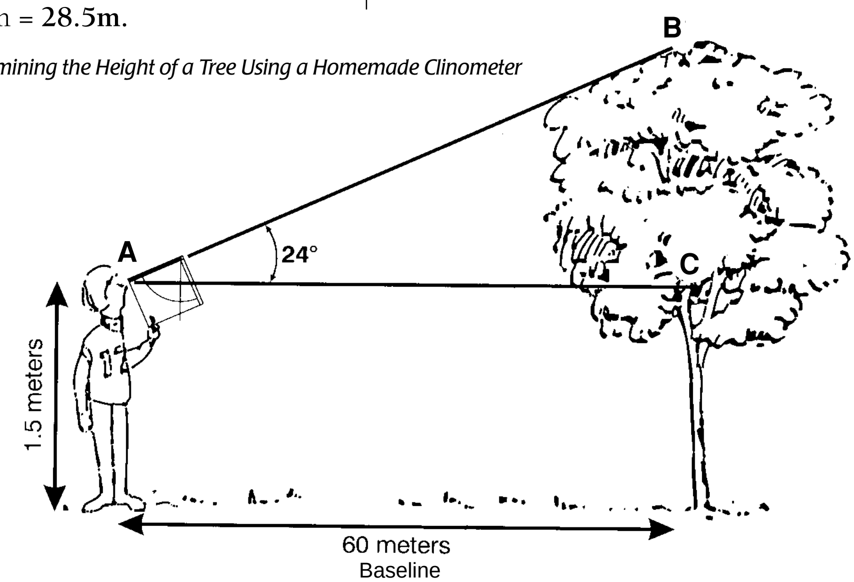
Step 5: Repeat the Above Process for All Selected Trees

Step 6: Calculate and Record Average Tree Height(s)

- ❑ Add the heights (in meters) of the dominant species trees and divide by five to obtain their average height.
- ❑ If you have five co-dominant species trees, repeat the process for them.
- ❑ Record tree height averages on your Data Work Sheet.

Note: If you would like to practice measuring heights before going to your site, find a tall outdoor object for which you know or can directly measure the height (such as a flagpole or the school building). After completing the above process, compare your results with the known height of the object.

Figure LAND-P-15: Determining the Height of a Tree Using a Homemade Clinometer

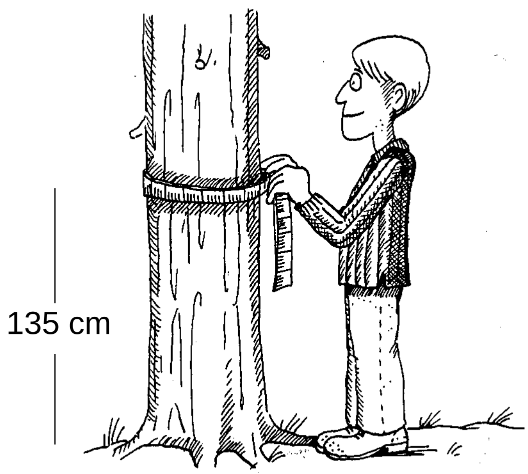


How To Measure Tree Circumference

Step 1: Measure and Record Tree Circumference

- ❑ With a flexible tape measure, measure the tree's circumference at exactly 1.35 m above ground level. Scientists call this measurement *circumference at breast height* (*CBH*).
- ❑ Repeat process for all five dominant species trees and, when applicable, all five co-dominant species trees.
- ❑ Record circumferences in centimeters on your Land Cover/Biology Investigation Field Data Work Sheet.

Figure LAND-P-16: Measuring Tree Circumference



Source: Jan Smolík, 1996, TEREZA, Association for Environmental Education, Czech Republic

How To Measure Grass Biomass

If the dominant and/or co-dominant species at your site is grass, you will measure the *biomass* - the total mass of both live (green) and *senescent* (brown) herbaceous vegetation - per square meter on your site. This data will help others to document land cover and to assess and model water and nutrient cycles. Do not measure the biomass of any vegetation other than grasses, even if they are the dominant or co-dominant species present.

Step 1: Select and Mark Three Random Sampling Locations

- ❑ Blindfold a student and have him or her throw a small bean bag while you spin him or her at the center of your site. The bean bag's landing point will be one random sampling location.
- ❑ Repeat process twice more.
- ❑ At each sampling location, use a tape measure to mark out a one meter square on the ground.

Step 2: Collect and Sort Grass Clipping Samples

- ❑ Use garden clippers to clip all the grass vegetation within the square. When completed, the square should be devoid of any grass vegetation except for short stubs (*Vegetation* means it is still rooted in the ground. Do not collect any unattached leaves or litter).
- ❑ Sort clippings into living and senescent portions. Any clipping with even a little green is considered living. Only entirely brown clippings are senescent.
- ❑ Place the living and senescent portions into separate brown paper (*not* plastic) bags, and label each bag carefully. If your site has very extensive growth, use several small bags instead of two large ones.

Step 3: Prepare and Weigh Grass Clipping Samples

- ❑ Back at school, dry the bags over a period of days in a drying oven at a temperature no higher than 50 to 70 degrees celsius. Weigh each bag once a day. The samples are completely dry when you get the same mass on two consecutive days. (**Note:** Do *not* use a conventional cooking oven for this process; that would dangerous!)
- ❑ Weigh each bag, one at a time. Then, shake out the contents and weigh the empty bag. Subtract the empty bag weight from the total weight to get the weight of the grass. (Use a scale capable of measuring weights to plus or minus 0.1 g.)

Step 4: Record and Report Findings

- ❑ Record the weight in grams of both the green and brown material from each sample location.
- ❑ Report the weights of green and brown material for each of the three samples to the GLOBE Student Data Server.
- ❑ Calculate the average weight (biomass) of green material by adding the weights of the three samples and dividing by three. Record this weight in the Biometry Summary section of the Land Cover/ Biology Investigation Field Data Work Sheet for future reference and comparison.
- ❑ Calculate the average weight (biomass) of brown material by adding the weights of the three samples and dividing by three. Record this weight in the Biometry Summary section of the Land Cover/ Biology Investigation Field Data Work Sheet for future reference and comparison.

How to Enter Your Observations on the Land Cover/Biology Investigation Field Data Work Sheet

You will find a Land Cover/Biology Investigation Field Data Work Sheet in the *Appendix*, which you can use to record site observations and measurements. Make as many blank copies of this work sheet as you need. Use a separate work sheet each time your students make observations. This work sheet contains spaces to record every possible ground observation and measurement in this protocol. Depending upon what observations or measurements you make, some spaces will be left blank.

Your students should record the following data and information on the Land Cover/Biology Investigation Field Data Work Sheet:

1. **Site Identification:** Identify your Land Cover Sample Site. Designate the visit as either "training" or "validation" and as either "qualitative" or "quantitative." If it is a quantitative site, record whether it is your Biology Study Site.
2. **Site Name:** Identify the name you and your students give to your study site.
3. **Country/State/City:** Identify your locality using these identifiers.
4. **GPS Location:** Record the latitude and longitude of your site's center point, which has been determined using GPS.
5. **Date and Time:** Record the date and time of your field observations and measurements.
6. **Recorded By:** Record the name of the student or other person entering data on the form.
7. **MUC Land Cover Classes 2, 3, and 4:** Record the name and numerical code of the best match to your site's cover type as determined by the Modified UNESCO Classification System (MUC). If your cover is *urban* or *agricultural*, you may stop. All other observations and measurements are for natural vegetation.

8. **Dominant and Co-Dominant Species:**
   - If your dominant and/or co-dominant species are trees, enter the first four letters of the genus and species of each (as labeled in a dichotomous key).
   - If your dominant and/or co-dominant species are herbaceous vegetation, enter either “GRAM,” for grass (graminoid), or “FORB” for other, broad-leaved vegetation.
   - If the vegetation on your site is diverse and the dominant and co-dominant species are impossible to ascertain, describe the vegetation types well in the Notes, Photographs section (below) and enter “mixed” on these lines.
9. **Canopy Cover:** Record + and - observations when using the densiometer method.
10. **Ground Cover:** Record the G, B, and - observations for ground cover.
11. **Number, Height, and Circumference of Trees:** Record the number of trees and the height and circumference measurements on your five dominant and five (when applicable) co-dominant tree species specimens. (If grasses are the dominant and co-dominant vegetation, leave these fields blank.)
12. **Green/Brown Biomass:** If your sample is dominated by grasses, record the green and brown biomasses for each of your sample locations after drying your samples at school. (If grass is not the dominant vegetation, leave these fields blank.)
13. **Biometry Summary:** Record the calculated canopy cover percentages, the green and brown ground cover percentages, the average tree height and circumference, and the average grass biomass obtained from combining the multiple samples.

    Note: Report all items marked by a star on the data form to the GLOBE Student Data Server.
14. **Notes, Photographs:** Record relevant field observations such as weather conditions, the number and orientation of photographs taken, etc.

MUC System Protocol

Purpose

To classify land cover using the Modified UNESCO Classification (MUC) System

Overview

Students will learn how to use this hierarchical classification system to assign a MUC class to their land cover sample sites.

Time

15 to 45 minutes to make field observations and determine proper MUC class (excluding travel time to and from the site)

Level

All

Frequency

For land cover samples sites: Determine MUC class once during peak foliage

Key Concepts

Canopy cover
Ground cover
Hierarchical land cover classification system

Skills

Using a compass
Measuring distances with paces
Using classification systems
Deciding based on definitions and rules
Identifying tree and ground cover types
Using the MUC system to identify the land cover class of a land cover sample site

Materials and Tools

MUC system and definitions
Compass
Tubular densiometer
Biometry Data Work Sheet

Preparation

Review the MUC system and the classification examples.

Identify MUC classes that are applicable to your local area.

Prerequisites

Leaf Classification Learning Activity

Learn to pace.

Learn to use the compass and densiometer.

Introduction

In GLOBE, we use the Modified UNESCO Classification (MUC) System for classifying land cover. MUC has an ecological basis and follows international standards. The MUC system has four levels of classification arranged hierarchically. As you can see in Tables LAND-P-3 and LAND-P-4 each higher level is based on more detailed properties of land cover. MUC codes of up to four digits are associated with each MUC class with one digit for each level in the class beginning with the lowest level. In assigning a MUC class to a homogeneous area of land cover, always begin at the lowest level (i.e. the first digit of the MUC code) and proceed up the levels one-by-one. The definitions of the MUC classes are given in the *Appendix*, and students should always refer to these definitions rather than trusting their memories or general knowledge when determining the MUC class for an area.

A classification system is a comprehensive set of categories, with labels and definitions, typically arranged in a hierarchy or branching structure. A classification system is used to organize a set of data, such as an inventory of land cover types, into meaningful groups. The classification system must be both *totally exhaustive* and *mutually exclusive*. A *totally exhaustive* classification has an appropriate class for every possible data point (e.g., land cover type). A *mutually exclusive*

Table LAND-P-3: MUC Level 1 and 2

	Level 1	Level 2
Natural Cover	0 Closed Forest	01 Mainly Evergreen Forest 02 Mainly Deciduous Forest 03 Extremely Xeromorphic (Dry) Forest
	1 Woodland	11 Mainly Evergreen Woodland 12 Mainly Deciduous Woodland 13 Extremely Xeromorphic (Dry) Woodland
	2 Shrubland	21 Mainly Evergreen Shrubland 22 Mainly Deciduous Shrubland 23 Extremely Xeromorphic (Dry) Shrubland
	3 Dwarf-shrubland	31 Mainly Evergreen Dwarf-shrubland 32 Mainly Deciduous Dwarf-shrubland 33 Extremely Xeromorphic Dwarf-shrubland 34 Tundra
	4 Herbaceous Vegetation	41 Tall Graminoid 42 Medium Tall 43 Short Graminoid 44 Forb (broad-leaved) Vegetation
	5 Barren Land	51 Dry Salt Flats 52 Sandy Areas 53 Bare Rock 54 Perennial Snowfields 55 Glaciers 56 Other
	6 Wetland	61 Riverine 62 Palustrine 63 Estaurine 64 Lacustrine
	7 Open Water	71 Freshwater 72 Marine
Developed Cover	8 Cultivated Land	81 Agriculture 82 Non-agriculture
	9 Urban	91 Residential 92 Commercial/Industrial 93 Transportation 94 Other

Sources: UNESCO, 1973 and GLOBE, 1996

classification has one and only one appropriate class for every data point. The hierarchical arrangement means that there are multiple levels of classes: level 1 has the most general classes; each higher level in the system increases in detail and multiple detailed classes may be condensed into fewer more general classes. For example:

The MUC System has ten level 1 classes, including *Closed Forest, Woodland,* and *Urban*. See Tables LAND-P-3 and LAND-P-4. The level 2 classes within *Closed Forest* are *Mainly Evergreen Forest, Mainly Deciduous Forest,* and *Extremely Xeromorphic (dry) Forest*. These level 2 classes contain more detail than the level 1 class, *Closed Forest*, and they may all be collapsed into the *Closed Forest* class. In other words, any member of one of these three Level 2 classes is always a member of the *Closed Fores*t level 1 class. Table LAND-P-3 is a condensed version of MUC, showing only the level 1 and level 2 classes.

The entire MUC classification system is outlined in Table LAND-P-4. Be aware that this outline contains only the name and identifying code number of each class. The full definition and description of each class is detailed in the Glossary of Terms for the Modified UNESCO Classification System. The Glossary is found in the *Appendix*. Each class is strictly defined by clear decision criteria.

An Example of Determining MUC Class to Level 2

Figure LAND-P-17 illustrates the criteria used to distinguish between Forest and Woodland classes at MUC level 1 criteria used to distinguish between Mainly Deciduous, Mainly Evergreen, and Mainly Xeromorphic cover types at level 2.

More than 40% of the land cover sample must be covered by trees to qualify as forest or woodland. If the tree crowns are interlocking (branches from neighboring trees touch each other) the sample site is considered forest. If the trees are spread farther apart and branches do not touch each other, the sample site is considered woodland. The level 2 classes typically depend on the composition of the level 1 cover type. In this example, the level 2 class for Forest or Woodland depends upon the percentage of deciduous and evergreen trees in the canopy.

Figure LAND-P-17: Applying MUC to Forest and Woodland

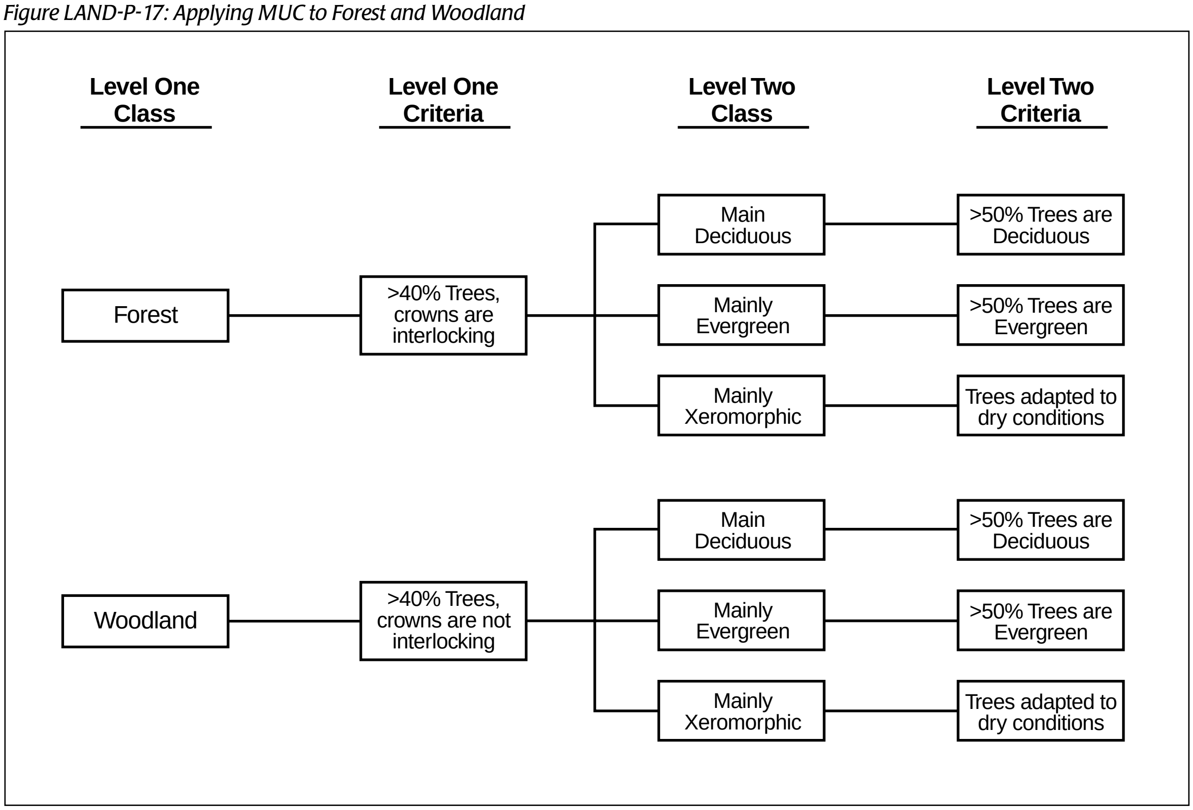


Table LAND-P-4: MUC Level 1 –4

	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	NOTES AND EXAMPLES
Natural Cover	0 Closed Forest	01 Mainly Evergreen Forest	011 Tropical Wet (Rain) Forest	0111 Lowland forest	
				0112 Submontane forest	Costa Rica: Atlantic slope
				0113 Montane forest	Costa Rica: Sierra de Talamanca
				0114 "Subalpine" forest	
				0115 Cloud forest	Jamaica: Blue Mountains
			012 Tropical and Subtropical Evergreen Seasonal	0121 Lowland forest	
				0122 Submontane forest	
				0123 Montane forest	
				0124 "Subalpine" forest	
			013 Tropical and Subtropical Semi-deciduous	0131 Lowland forest	*Ceiba spp.*
				0133 Montane or cloud forest	
			014 Subtropical Wet Forest	0141 Lowland forest	Queensland, Australia, and Taiwan
				0142 Submontane forest	
				0143 Montane forest	
				0144 "Subalpine" forest	
				0145 Cloud forest	
			015 Temperate and Subpolar Evergreen Wet Forest	0151 Temperate evergreen wet forest	Chilean Coast
				0152 Subpolar evergreen wet forest	
			016 Temperate Evergreen with Deciduous Broad-leaved	0161 Lowland forest	
				0162 Submontane forest	
				0163 Montane forest	
				0164 "Subalpine" forest	
			017 Winter-Rain Evergreen Broad-leaved Sclerophyllous	0171 Lowland and submontane	*Eucalyptus regnans, E. diversicolor*
				0172 Lowland and subm. <50m tall	USA: California live-oak forest
			018 Tropical and Subtropical Evergreen Needle-leaved	0181 Lowland and submontane	*Pinus spp. forest of Honduras and Nicaragua*
				0182 Montane and subalpine	*Pinus spp. forest of Phillippines and southern Mexico*
			019 Temperate and Subpolar Evergreen Needle-leaved	0191 Giant forest (>50 m)	*Sequoia and Pseudotsugaspp., Pacific W. of N. America*
				0192 (Irregularly) Rounded crowns	*Pinus spp.*
				0193 Conical crowns	*Picea and Abies spp.; USA California Red Fir forests*
				0194 Cylindrical crowns	Boreal, short branches

Table LAND-P-4: MUC Level 1 –4 (continued)

LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	NOTES AND EXAMPLES
Natural Cover				
0 Closed Forest	02 Mainly Deciduous Forest	021 Tropical and Subtropical Drought-deciduous	0211 Broad-leaved lowland and submontane	Northwest Costa Rica
			0212 Montane and cloud forest	Northern Peru
		022 Cold-deciduous Forest with Evergreen Trees and Shrubs	0221 With evergreen broad-leaved trees and climbers	Western Europe: Ilex aquifolium, Hedera helix North America: Magnolia spp.
			0222 With evergreen needle-leaved trees	Northeastern US: maple-hemlock forest
		023 Cold-deciduous Forest without Evergreen Trees	0231 Temperate lowland and submontane broad-leaved	
			0232 Montane or boreal	
			0233 Subalpine or subpolar	Grades into woodland
	03 Extremely Xeromorphic (Dry) Forest	031 Sclerophyllous-dominated		
		032 Thorn-forest	0321 Mixed deciduous-evergreen	
			0322 Purely deciduous	
		033 Mainly Succulent Forest		
1 Woodland	11 Mainly Evergreen	111 Evergreen Broad-leaved		
		112 Evergreen Needle-leaved	1121 Rounded crowns	*Pinus spp.*
			1122 Conical crowns prevailing	Mostly subalpine
			1123 Narrow cylindrical crowns	Boreal regions: Picea spp.
	12 Mainly Deciduous	121 Drought-deciduous	1211 Broad-leaved lowland and submontane	
			1212 Montane and cloud forest	
		122 Cold-deciduous with Evergreens	1221 With evergreen broad-leaved trees and climbers	
			1222 With evergreen needle-leaved trees	
		123 Cold-deciduous without Evergreens	1231 Broad-leaved deciduous	
			1232 Needle-leaved deciduous	
			1233 Mixed deciduous	
	13 Extremely Xeromorphic (Dry)	131 Sclerophyllous-dominated		
		132 Thorn-forest	1321 Mixed deciduous-evergreen	
			1322 Purely deciduous	
		133 Mainly Succulent Forest		

Table LAND-P-4: MUC Level 1 –4 (continued)

	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	NOTES AND EXAMPLES
Natural Cover	2 Shrubland	21 Mainly Evergreen	211 Evergreen Broad-leaved	2111 Low bamboo thicket	
				2112 Evergreen tuft-tree	Mediterranean dwarf-palm, Hawaiian tree-fern
				2113 Broad-leaved hemisclerophyllous	Subalpine Rhododendron thickets, or Hibiscus tiliaceeus matted thickets of Hawaii, USA
				2114 Broad-leaved sclerophyllous	Chapparral or macchia
				2115 Suffruticose thicket	*Cistusheath*
			212 Evergreen Needle-leaved and Microphyllous	2121 Evergreen needle-leaved	*Pinus mughus, "Krummholz"*
				2122 Evergreen microphyllous	Tropical subalpine
		22 Mainly Deciduous	221 Drought-deciduous Mixed with Evergreen Woody Plants		
			222 Drought-deciduous without Evergreens		
			223 Cold-deciduous	2231 Temperate deciduous	
				2232 Subalpine or subpolar	
		23 Extremely Xeromorphic (Dry)	231 Mainly Evergreen	2311 Evergreen subdesert	
				2312 Semi-deciduous subdesert	Australia, N. America: Atriplex-Kochia-saltbush
			232 Deciduous Subdesert	2321 Without succulents	
				2322 With succulents	
	3 Dwarf-Shrubland	31 Mainly Evergreen	311 Evergreen Dwarf-shrub Thicket	3111 Caespitose thicket	*Calluna heath*
				3112 Creeping or matted thicket	*Loiseleuria heath*
			312 Evergreen Dwarf-shrubland	3121 Evergreen cushion	E. Mediterranean: Astragalus and Acantholimonspp.
			313 Mixed Evergreen and Herbaceous Formation	3131 True evergreen & herbaceous mixed	*Nardus-Calluna heath*
				3132 Partial evergreen & herbaceous mixed	Greece: Phryganaspp.
		32 Mainly Deciduous	321 Facultative Drought-deciduous		
			322 Obligate Drought-deciduous	3221 Drought-deciduous caespitose	
				3222 Drought-deciduous creeping or matted	
				3223 Drought-deciduous cushion	
				3224 Drought-deciduous mixed	
			323 Cold-deciduous	3231 Drought-deciduous caespitose	
				3232 Drought-deciduous creeping or matted	
				3233 Drought-deciduous cushion	
				3234 Drought-deciduous mixed	

Table LAND-P-4: MUC Level 1 –4 (continued)

	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	NOTES AND EXAMPLES
Natural Cover	3 Dwarf-Shrubland	33 Extremely Xeromorphic	331 Mainly Evergreen	3311 Evergreen subdesert	
				3312 Semi-deciduous subdesert	
			332 Deciduous Subdesert	3321 Without succulents	
				3322 With succulents	
		34 Tundra	341 Mainly Bryophyte	3411 Caespitose	
				3412 Creeping or matted	
			342 Mainly Lichen		
	4 Herbaceous Vegetation	41 Tall Graminoid	411 With Trees Covering 10-40 %	4110 Trees: needle-leaved evergreen	
				4111 Trees: broad-leaved evergreen	
				4112 Trees: broad-leaved semi-evergreen	
				4113 Trees: broad-leaved deciduous	
			412 With Trees < 10 %	4120 Trees: needle-leaved evergreen	
				4121 Trees: broad-leaved evergreen	
				4122 Trees: broad-leaved semi-evergreen	
				4123 Trees: broad-leaved deciduous	
				4124 Tropical or subtropical with trees and shrubs in tufts on termite nests	Termite savannah
			413 With Shrubs	4130 Shrubs: needle-leaved evergreen Shrubs:	
				4131 broad-leaved evergreen	
				4132 Shrubs: broad-leaved semi-evergreen	
				4133 Shrubs: broad-leaved deciduous	
				4134 Tropical or subtropical with trees & shrubs in tufts on termite nests	Termite savannah
			414 With Tuft Plants (usu. palms)	4141 Tropical with palms	Bolivia: Arocomia totai and Attalea princeps
			415 Without Woody Synusia	4151 Tropical	Low-latitude Africa, lower Amazon, upper Nile
		42 Medium Tall	421 With Trees Covering 10-40 %	4210 Trees: needle-leaved evergreen Trees:	
				4211 broad-leaved evergreen	
				4212 Trees: broad-leaved semi-evergreen	
				4213 Trees: broad-leaved deciduous	
			422 With Trees < 10 %	4220 Trees: needle-leaved evergreen Trees:	
				4221 broad-leaved evergreen	
				4222 Trees: broad-leaved semi-evergreen	
				4223 Trees: broad-leaved deciduous	
				4224 Tropical or subtropical with trees & shrubs in tufts on termite nests	Termite savannah

Table LAND-P-4: MUC Level 1 –4 (continued)

LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	NOTES AND EXAMPLES
4 Herbaceous Vegetation	42 Medium Tall	423 With Shrubs	4230 Shrubs: needle-leaved evergreen Shrubs:	
			4231 broad-leaved evergreen	
			4232 Shrubs: broad-leaved semi-evergreen	
			4233 Shrubs: broad-leaved deciduous	
			4234 Tropical or subtropical with trees & shrubs in tufts on termite nests	Termite savannah
			4235 Woody synusia of deciduous thorny shrubs	
		424 Open Synusia of Tuft Plants	4241 Subtropical with open palm groves	
		425 Without Woody Synusia	4251 Mainly sod grasses	USA, Eastern Kansas: tall-grass prairie
			4252 Mainly bunch grasses	New Zealand: Festuca novac-zelandiae
	43 Short Graminoid	431 With Trees Covering 10-40 %	4310 Trees: needle-leaved evergreen Trees:	
			4311 broad-leaved evergreen	
			4312 Trees: broad-leaved semi-evergreen	
			4313 Trees: broad-leaved deciduous	
		432 With Trees < 10 %	4320 Trees: needle-leaved evergreen Trees:	
			4321 broad-leaved evergreen	
			4322 Trees: broad-leaved semi-evergreen	
			4323 Trees: broad-leaved deciduous	
			4324 Tropical or subtropical with trees & shrubs in tufts on termite nests	Termite savannah
		433 With Shrubs	4330 Shrubs: needle-leaved evergreen Shrubs:	
			4331 broad-leaved evergreen	
			4332 Shrubs: broad-leaved semi-evergreen	
			4333 Shrubs: broad-leaved deciduous	
			4334 Tropical or subtropical with trees & shrubs in tufts on termite nests	Termite savannah
			4335 Woody synusia of deciduous thorny shrubs	
		434 Open Synusia of Tuft Plants	4341 Subtropical with open palm groves	
		435 Mainly Bunch Grasses with Woody Synusia	4351 Tropical alpine with tuft plants	
			4352 Tropical alpine, but very open, with no tuft plants	
			4353 Tropical or subtropical with open stands of evergreens	
			4354 With dwarf-shrubs	
		436 Without Woody Synusia	4361 Short-grass communities	USA, Colorado: short-grass prairie
			4362 Bunch-grass communities	
		437 Short to Medium Tall Mesophytic Communities	4371 Sodgrass communities	N. America, Eurasia: Low altitude, cool, humid
			4372 Alpine, subalpine meadows	High latitudes

Table LAND-P-4: MUC Level 1 –4 (continued)

	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	NOTES AND EXAMPLES
Natural Cover	4 Herbaceous Vegetation	44 Forb Vegetation	441 Tall Forb Communities	4411 Fern thickets	
				4412 Mainly annual forbs	
			442 Low Forb Communities	4421 Mainly perennial flowering forbs and ferns	
				4422 Mainly annual forbs	
	5 Barren Land	51 Dry Salt Flats			
		52 Sandy Areas			
		53 Bare Rock			
		54 Perennial Snowfields			
		55 Glaciers			
		56 Other			
	6 Wetland	61 Riverine			
		62 Palustrine			
		63 Estuarine			
		64 Lacustrine			
	7 Open Water	71 Freshwater			
		72 Marine			
Developed Cover	8 Cultivated Land	81 Agriculture	811 Row Crop or Pasture		
			812 Orchard or Horticulture		
			813 Confined Livestock feeding		
			814 Other Agriculture		
		82 Non-agriculture	821 Parks and Athletic fields		
			822 Golf Courses		
			823 Cemeteries		
			824 Other Non-agriculture		
	9 Urban	91 Residential			
		92 Commercial/Industrial			
		93 Transportation			
		94 Other			

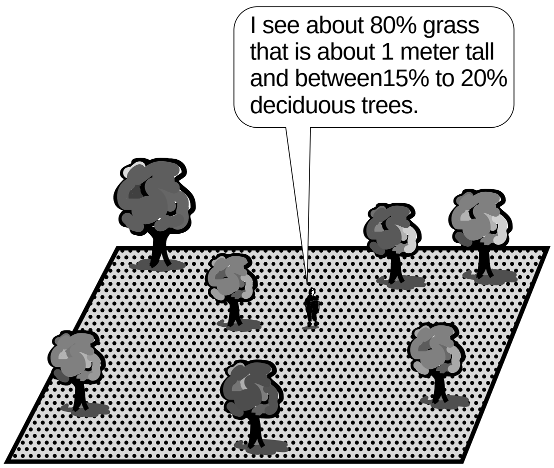
Sources: UNESCO, 1973 and GLOBE, 1996

Additional Examples of How to Use the MUC System

The following examples demonstrate the classification process. Refer to the MUC outline (Table LAND-P-4), and to the MUC Glossary in the *Appendix* as you read them.

Example 1

For your Land Cover Sample Site (90 m x 90 m) you pick a relatively homogeneous area of grasses. About 80% of the site is covered by grass and herbaceous plants about 1 meter tall (a 75/25 mix, respectively), and about 15-20% by broad-leaved deciduous trees.



Level 1: You see on the MUC Classification that class 4, Herbaceous Vegetation is probably the appropriate level 1 class. In the MUC Glossary, you see that class 4 requires greater than 60% total ground coverage of herbaceous vegetation over the entire study site, confirming that class 4 is appropriate.

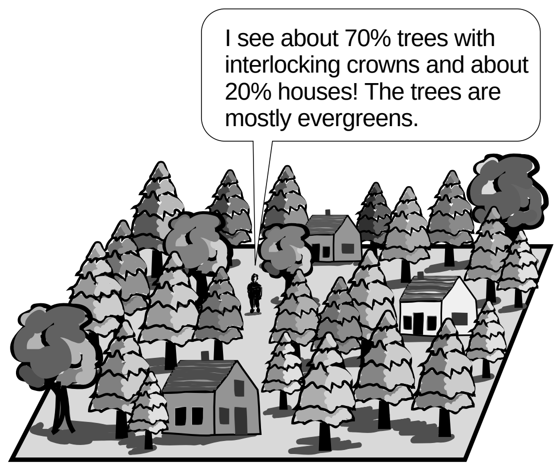
Level 2: On the *MUC Classification*, you now see four choices at level 2 (41-44). After reviewing the definitions of these four classes in the MUC Glossary, you determine that, since the dominant cover type (herbaceous) is more than 50% grass, the level 2 cover type must be Graminoid. Since the grass is between 50 cm and 2 m tall, you select class 42, Medium Tall Graminoid.

Level 3: On the *MUC Classification*, you now have five Level 3 choices (421-425). Since trees cover 15-20% of the study site, you select Class 421, "With trees covering 10-40%", confirming this selection with the MUC Glossary definition.

Level 4: You now have three choices at Level 4 (4211-4213). Since the trees are broad-leaved deciduous, you select class 4213, and you have completed your MUC level 4 classification.

Example 2

You live in a lowland temperate region. You select a Land Cover Sample Site that is mostly forested with the tree crowns touching each other, but about 20% of the ground area has houses on it. Of the trees, it looks like there are more evergreen than deciduous trees, probably a 60/40 split.



Level 1: On the *MUC Classification* you check your Level 1 choices and find that, since the tree crowns are interlocking, and there is more than 40% canopy cover over the entire study site, Closed Forest, class 0, is the level 1 class.

Level 2: You now have three level 2 choices (01-03). Since at least 50% of the trees that reach the canopy are evergreen, you select class 01, Mainly Evergreen at level 2.

Level 3: You now have nine level 3 choices (011-019), but five are explicitly tropical and subtropical. A sixth choice is a winter-rain category which is also clearly not appropriate. So you have only three categories to seriously consider (015, 016, 019), and after consulting the MUC Glossary you select 016, Temperate Evergreen with Deciduous Broad-leaved.

Level 4: Now you have four level 4 choices (0161-0164). Since you live in a lowland area, class 0161, Lowland forest is the appropriate selection.

How to Classify Land Cover Using the MUC System

When classifying land cover using the MUC system, always begin with the most general classes (level 1) and proceed sequentially to the more detailed (higher level) classes. There are ten level 1 land cover classes in MUC. Eight of these choices are natural land cover and two are developed. At no other level in the MUC system are there more than six land cover choices, and therefore, the level 1 choice among ten classes is the most challenging decision to make. However, given that these ten classes are the most general, the distinctions among them are broad and the decision as to which level 1 land cover class to pick is usually not difficult. Always refer to the definitions for each land cover class to help you in choosing the appropriate class at every level.

How to Classify Land Cover to MUC Level 1

Step 1: Eliminate as many MUC level 1 classes as possible.

- ❑ Compare the Land Cover Sample Site with the definitions of the 10 MUC level 1 classes.
- ❑ Usually there are only a few level 1 classes that can possibly match your site; eliminate the others from consideration.

Step 2: Make any measurements necessary to determine the MUC level 1 class.

- ❑ Perform measurements of tree height, canopy cover, or ground cover and identify dominant and co-dominant species as necessary to distinguish between different MUC level 1 classes. Follow the appropriate portions of the Biometry Protocol. In many cases no measurements will be necessary.
- ❑ Using the quantitative measurements, resolve any questions and assign a MUC level 1 class to this site.

Step 3: Check your assignment.

Read the definitions for the MUC levels 2, 3, and 4 for your chosen MUC level 1 class that are possible for your area. If none of the definitions of higher level MUC classes match your site, reconsider your choice of MUC level 1 class in Step 2.

How to Classify Land Cover Sample to MUC levels 2, 3, and 4

Step 1: Determine the MUC level 2 class.

- ❑ Review the level 2 definitions that apply to the MUC level 1 class of your site.
- ❑ Select the MUC level 2 class that applies to your site.
- ❑ If necessary, make measurements of the vegetation on your site to resolve quantitative distinctions between different level 2 classes using the procedures given in Using Field Observations to Determine MUC Class.

Step 2: Determine the MUC level 3 class.

- ❑ Review the level 3 definitions that apply to the MUC level 2 class of your site. If there are none, record your MUC level 2 class (two digits); you have completed this protocol.
- ❑ Select the MUC level 3 class that applies to your site.
- ❑ If necessary, make additional measurements of the vegetation on your site to resolve quantitative distinctions between different level 3 classes using the procedures given in *Using Field Observations to Determine MUC Class.*

Step 3: Determine the MUC level 4 class.

- ❑ Review the level 4 definitions that apply to the MUC level 3 class of your site. If there are none, record your MUC level 3 class (three digits); you have completed this protocol.
- ❑ Select the MUC level 4 class that applies to your site.
- ❑ If necessary, make additional measurements of the vegetation on your site to resolve quantitative distinctions between different level 4 classes using the procedures given in *Using Field Observations to Determine MUC Class.*
- ❑ Record your MUC level 4 class.

Using Field Observations to Determine MUC Class

Distinguishing among some MUC classes requires quantitative measurements of the percentage of your site that is covered by different types of vegetation. This can be accomplished using modified versions of the Canopy and Ground Cover measurement procedures of the *Biometry* Protocol. You can identify the appropriate MUC class by calculating the percentages of the vegetation types observed at the Land Cover Sample Site. Use the *Dominant/Co-Dominant Vegetation Data Work Sheet* to add up your canopy and/or ground cover observations. You can calculate percentages of deciduous and evergreen canopy cover, and graminoid and forb ground cover in addition to the total canopy cover and green, brown, and total ground cover measurements presented in the Biometry Protocol.

Determining the Percentage of Tree Cover That is Evergreen or Deciduous

Step 1: Make a modified canopy cover measurement.

- ❑ Repeat the canopy cover measurement from the Biometry Protocol but at each location note "E" if the canopy touching the crosshairs is part of an evergreen tree and "D" if the canopy touching the crosshairs is part of a deciduous tree.

Step 2: Calculate the percentage of the canopy that is evergreen or deciduous.

- ❑ Divide the number of E observations (or D observations) by the sum of the E's and the D's and multiply by 100. If the percentage of evergreen species is greater than 50%, then the site is considered mainly evergreen.

Determining the Composition of Herbaceous Coverage:

Step 1: Make a modified measurement of ground cover.

- ❑ Repeat the ground cover measurement from the Biometry Protocol, but instead of noting whether vegetation is green or brown, note whether it is graminoid (grass) or forb (broad leafed) and record a "GD" if the vegetation under foot or touching the ankle or leg below the knee is a graminoid and an "FB" if it is a forb.

Step 2: Calculate the percentage of ground cover that is graminoid or forb.

- ❑ Divide the number of GD measurements (or FB measurements) by the sum of the GD's and FB's and multiply by 100 to obtain a percentage. If the percentage of graminoid species is greater than 50%, then the sample is considered graminoid. Conversely, if the percentage of forb is greater than 50%, then the sample is considered forb.

$$\%\ \text{Evergreen} = \frac{\#\ \text{of E's (evergreen observations)}}{\#\ \text{of E's} + \#\ \text{of D's (total canopy cover observations)}} \times 100$$

$$\%\ \text{Graminoid} = \frac{\#\ \text{of GD's (Graminoid Observations)}}{\#\ \text{of GD's} + \#\ \text{of FB's (Total \# of Herbaceous Ground Observations)}} \times 100$$

Determining Total Shrub Canopy Cover

If your site or area is one where the dominant land cover types is naturally occurring shrubland or dwarf shrubland (ornamental and cultivated shrubs do not count), you should slightly modify one of the preceding procedures. The equations for canopy cover percentage can be adapted to determine the total shrub canopy cover as well as the percentage of evergreen and deciduous shrubs.

Step 1: Determining the Amount of Shrub Cover

- ❑ If the canopy of the shrub cover is over head, carry out the canopy cover measurement from the Biometry Protocol. If the canopy cover touching the crosshairs is shrub record "SB", if it is a deciduous tree record "D", and if it is an evergreen tree record "E". If the shrubs are too short to make true canopy observations (i.e. they are too short to walk under), treat the shrubs as an additional ground cover category along with graminoid and forb. Carry out the ground cover measurement from the Biometry Protocol, recording "GD" if the vegetation touching the observer's body at any height is a graminoid, "FB" if the vegetation is a forb, and "SB" if it is a shrub.

Step 2: Calculate the Percentage of Shrub Cover

- ❑ If the shrub cover is over head, divide the number of SB measurements by the sum of the SB, D, and E measurements. If the shrubs are not overhead, divide the number of SB measurements by the sum of the SB, GD, and FB measurements. Multiply by 100 to obtain a percentage.

References

A land use and land cover classification system for use with remote sensor data. J.R. Anderson, E.E. Hardy, J.T. Roach, and R.E. Witmer. U.S. Geol. Surv. Prof. Pap., 1976.

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International classification and mapping of vegetation. United Nations Educational, Scientific and Cultural Organization. Switzerland: UNESCO, 1973.

NOAA Coastal Change Analysis Program (C-CAP): Guidance for Regional Implementation. J.E. Dobson et al. NOAA Technical Report NMFS 123, 1995.

$$\% \text{ Shrub} = \frac{\text{\# of SB's (Shrub Observations)}}{\text{\# of SB's + \# of E's + \# of O's (Total canopy cover observations)}} \times 100$$

OR

$$\% \text{ Shrub} = \frac{\text{\# of SB's (Shrub Observations)}}{\text{\# of SB's + \# of GD's + \# of FB's (Total ground cover observations)}} \times 100$$

Manual Interpretation Land Cover Mapping Protocol

Purpose

To produce a land cover map of your 15 km x 15 km GLOBE Study Site

Overview

Students visually interpret what they see in natural color and false color IR prints of the Landsat TM image of their GLOBE Study Site to create a hand-made land cover map of the area. The information on these maps, including MUC level 4 classifications, will help scientists check the accuracy of satellite derived land cover maps worldwide.

Time

Several class periods.

Level

All

Frequency

One time, but may be an iterative process as you progressively investigate more areas within your GLOBE Study Site.

Key Concepts

Land Cover classes
MUC Classification scheme

Skills

Interpreting land cover manually

Materials and Tools

512 X 512 false color IR print of your GLOBE Study Site (provided by GLOBE)
512 X 512 natural color print of your GLOBE Study Site (provided by GLOBE)
Topographic maps of your area
MUC Land Cover Classification System Table LAND-P-5 and definitions in the *Appendix*
Color photocopier (if available)
Clear plastic sheets or blank transparencies
Tape
Felt-tipped markers
Manual Classification Tutorial in the *Toolkit*

Preparation

Review the MUC Land Cover Classification Chart, discuss and evaluate local land covers, review topographic maps, and discuss classification.

Prerequisites

Odyssey of the Eyes and *Some Like it Hot Learning Activities*

With this method, students use *image interpretation* - they visually interpret what they see in a print of their local TM image. This method may be less accurate than others because personal interpretation is subjective. Students identify and outline areas of different land cover class. Usually, water bodies will be easiest to identify, although cloud shadows sometimes resemble lakes and ponds. Others will be harder to distinguish. For example, hardwood forests may look spectrally similar to actively growing fields. The *false color* IR image makes bodies of water and vegetation types easier to distinguish, while other types of land cover may be easier to see on the natural color image. In areas on the images where you can not identify the type of land cover, you will need to field-check the areas using the *Qualitative* or *Quantitative Land Cover Sample Site Protocols.* Assign all land cover classes using the MUC system. For further information, see the *Manual Classification Tutorial* in the *Toolkit*.

Note: The remote sensing image you use may be a few years old. Land cover may have changed since the image was taken. What you identify on the Landsat TM image may be different than what you see in your ground assessments. In this case, students should work to determine what was on the site at the time the satellite made the image.

Step 1: Create Your Land Cover Map

- ❑ Give students the false color IR print of the Landsat TM image of your GLOBE Study Site. Generally, each color on the IR map represents a different land cover class.

  Red represents actively growing, green vegetation (bright red represents hardwoods and fields, dark red represents evergreens).

  Black represents water.

  Blue represents urban areas and bare soils.
- ❑ Since the original print of your area provided by GLOBE is usually approximately 25 cm x 25 cm, try to enlarge various sections of it on a color copier to several times their original size. Four or more small groups of students can work on different enlarged portions of the original scene.
- ❑ Take a sheet of clear plastic large enough to cover your image. Place the plastic on top of the image and hold it in place with tape. Mark the location of the image corners on the plastic so it can be placed back in the same position if it is removed.
- ❑ Using felt-tipped marking pens, carefully outline areas of similar land cover class. Use a different color to represent each type. Assign each type the appropriate number from the MUC Land Cover Classification Chart. See Table LAND-P-5: MUC Level 1-4. If a group cannot identify a specific area, have a group or class discussion to try to identify it. Also ask a student living near the unidentified area to make an assessment of the land cover class from the MUC system on the way to or from school (students can return to such a site later and complete the *Qualitative* or *Quantitative Land Cover Assessment Protocols*). Students must be careful and specific when outlining areas and assigning classes. Start by identifying the most obvious features - usually bodies of water and urban areas - and then progress to more difficult types, such as different types of natural vegetation cover.
- ❑ Once each group has mapped their image section, combine the sections and compare results in order to identify problem areas. For instance, one group may identify an area in their section as "class 1192" (needle-leafed evergreen woodland), while a group mapping an *adjacent* section identifies their portion as "class 1222" (mixed deciduous and evergreen woodland).

Step 2: Report your results

- ❑ Once you identify all the areas on your image, transfer all MUC identifications onto a master copy and submit them to the address given in the *Implementation Guide*.

Unsupervised Clustering Land Cover Mapping

Purpose

To produce a land cover map of your 15 km x 15 km GLOBE Study Site

Overview

Students map land cover using a computer to recognize similar *spectral patterns* within the digital, 512 x 512 pixel Landsat Thematic Mapper data set provided by GLOBE for their GLOBE Study Site. These maps, classified to MUC level 4, will help scientists check the accuracy of worldwide land cover maps derived from satellite imagery.

Time

Several class periods

Level

Intermediate and Advanced

Frequency

One time, but may be an iterative process as you progressively investigate more areas within your GLOBE Study Site

Key Concepts

Land Cover classes
MUC Classification scheme
Clustering using spectral patterns

Skills

Using computers and MultiSpec software
Creating a land cover map

Materials and Tools

Computer

MultiSpec computer software (provided by GLOBE or downloaded from the Web)
512 x 512 pixel TM image data of your 15 km x 15 km GLOBE Study Site (provided by GLOBE)
MUC Land Cover Classification System and definitions

Preparation

Review the MUC Land Cover Classification Chart. Discuss and evaluate local examples of land cover, review topographic maps, and discuss classification.

Review the *MultiSpec Introduction to Image Processing* and *Unsupervised Classification - Clustering* in the *Toolkit*

Prerequisites

Odyssey *of the Eyes* and *Some Like it Hot Learning Activities*

In this protocol, GLOBE schools use the MultiSpec software to map land cover types. Students tentatively identify areas of similar land cover using the computer to recognize similar *spectral patterns* within the digital, 512 x 512 pixel Landsat TM data set for their area. These areas are grouped into *clusters*. The computer identifies and clusters together pixels in the image which have the most similar spectral properties. The software assigns each cluster an arbitrary color. Students then classify the land cover type of each cluster using the four levels of the MUC system.

Step 1: Create Your Map

- ❑ Start the MultiSpec program on your computer.
- ❑ Open the file containing the TM image of your GLOBE Study Site.
- ❑ Create a new project and select **Cluster** from the **Processor** menu.
- ❑ Select the appropriate number of clusters according to the number of groups you wish to classify (10 is recommended). Provide the system with other information as directed in the MultiSpec tutorial

section on Unsupervised Classification: Clustering.

- ❑ Once the image has been clustered, note the area included in each cluster. If you know the land cover of an area, assign a land cover class from the MUC system to the cluster. If you do not know the land cover of an area, use the data from a Land Cover Sample Site within the area to assign the land cover class from the MUC system. If there are no Land Cover Sample Sites within the area of a cluster, perform the *Qualitative* or *Quantitative Land Cover Protocol* for a site within this area. If there are multiple sample sites within an area, use only one of these sites to make the land cover class assignment and reserve the others for use in the *Accuracy Assessment Protocol*.
- ❑ Rename each cluster to correspond with its appropriate MUC Level 4 classification.

Step 2: Save Your Image and Report Data

- ❑ **Save** the classified clustered image. Use the **Project** menu to copy it onto a disk as a TIFF file. If you have a color printer, print copies of your students' land cover map(s).
- ❑ Report your data to the GLOBE Student Data Archive by sending a copy of the TIFF containing your classified, clustered map. Use the address given in the *Implementation Guide*.

Accuracy Assessment Protocol

Purpose

To quantitatively assess the accuracy of a land cover map

To identify the types of errors that occur on a land cover map

Overview

Students will perform an accuracy assessment on the land cover map they have generated either by manually interpreting or unsupervised clustering of the Landsat Thematic Mapper image of their GLOBE Study Site. Validation data collected at various Land Cover Sample Sites, which were not used in the development of the map, will be used to compare with the land cover map, and a difference/error matrix will be generated.

Time

Approximately 2 hours depending on the number of validation samples collected

Level

All

Frequency

Once for each land cover map. The accuracy assessment can be repeated when more validation sites have been measured; the statistical validity of the accuracy assessment improves as more samples are used.

An accuracy assessment can be performed on only a portion of the map.

Key Concepts

Accuracy assessment allows evaluation of our ability to map land cover.

The difference/error matrix

Skills

Building and *analyzing* a difference/error matrix for accuracy assessment

Solving problems cooperatively to resolve accuracy issues

Materials and Tools

Natural color, hard-copy TM image of your 15 km x 15 km GLOBE Study Site

False color infra-red, hard-copy TM image of your 15 km x 15 km GLOBE Study Site

MUC classification work sheet

Difference/error matrix work sheet

Preparation

Have copies of the necessary Work Sheets so the students can quickly compare the Land Cover Sample Sites to the appropriate location on the land cover map and generate the difference/error matrix.

Prerequisites

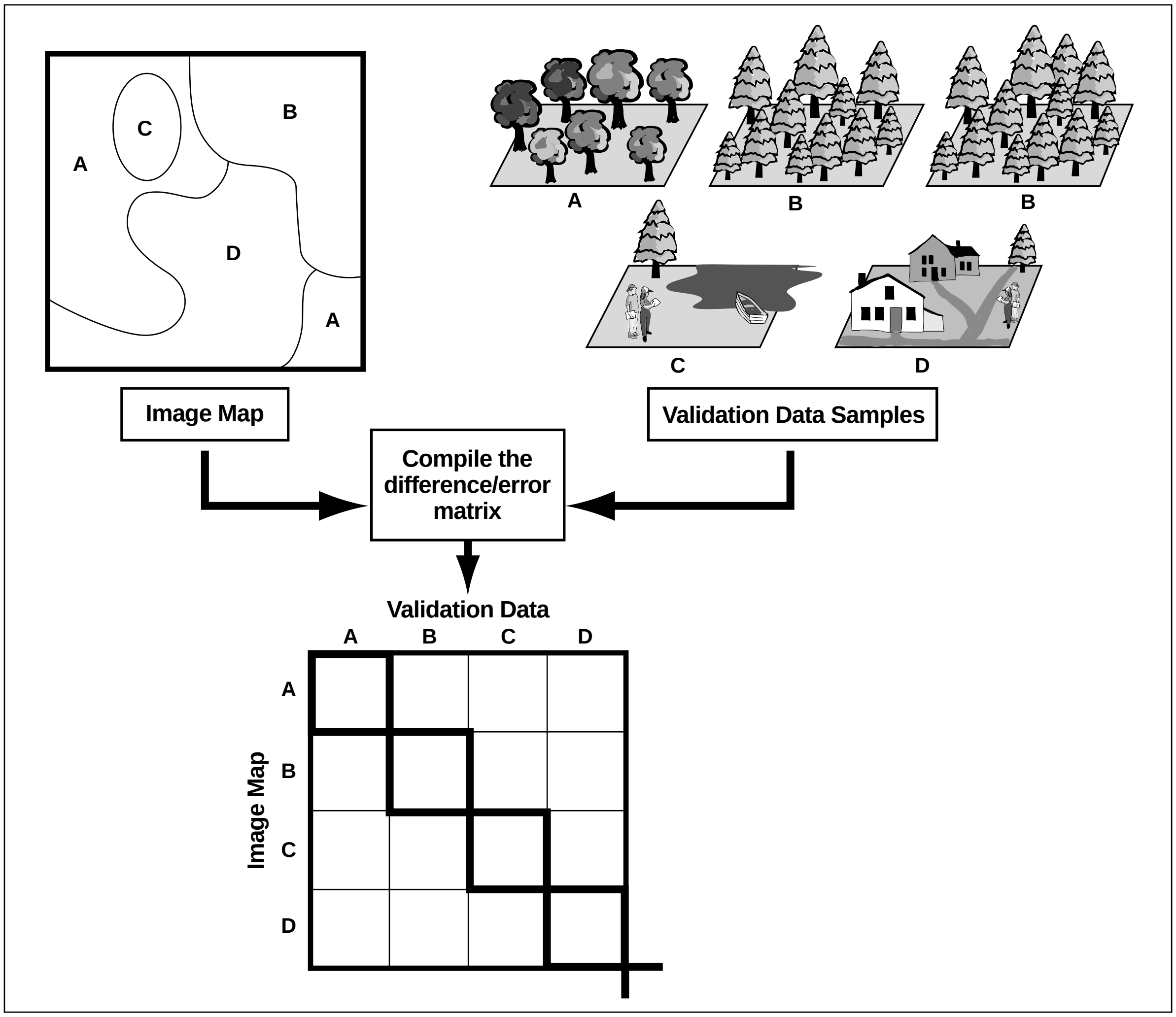
Either of the *Land Cover Mapping Protocols*

Introducing the Difference/Error Matrix Learning Activity

Introduction

In this protocol students will assess the accuracy of the land cover map generated from the remotely sensed data. See Figure LAND-P-18. It does not matter whether the land cover map was created through manual interpretation of an image or generated using the MultiSpec software and unsupervised clustering. In both cases, it is still important to compare the land cover map to Land Cover Sample Sites measured on the ground. A difference/error matrix will be generated to serve as a framework for analyzing the errors which occur in the land cover map. In the case of a land cover map generated from a satellite image using

Figure LAND-P-18: Accuracy Assessment Process



unsupervised clustering, some of the errors may be related to the fundamental limitations of the satellite image data as a tool in distinguishing land cover classes.

The following information is needed to generate a difference/error matrix:

- Land cover map generated from remotely sensed data
- Validation Land Cover Sample Sites

In order to generate a difference/error matrix, it is necessary to have validation data (Land Cover Sample Sites) collected for each land cover type in the Globe Study Site that you wish to assess. Ideally, it would be great to have samples for every land cover type. It may not be possible to collect all these samples and therefore, it may be desirable to only generate the matrix for the 3 or 5 most common types. The more samples collected for each land cover type, the more statistically valid the matrix will be. Over time, every school should be able to collect enough data to generate at least a limited difference/error matrix.

Once the validation data has been collected according to the protocols outlined in the *Qualitative* and *Quantitative Land Cover Sample Site Protocols*, it is possible to begin creating a difference/error matrix. This difference/error matrix should have a row and column for each and every MUC class that is on the MUC Classification Data Work Sheet (i.e. every MUC class that occurs for a land cover sample site or that labels any area on that portion of the land cover map that is being validated). See Table LAND-P-5. In this example there are four MUC classes: code 0222, code 0221, code 1121, and code 811. In the corresponding difference/error matrix (Table LAND-P-6), there is a column and a row for each of these four classes. For sample number 1 on the Example MUC Classification Data Work Sheet (Table LAND-P-5), you look up the Student MUC Classification for this area of the land cover map (Table LAND-P-5 cell A- Mainly cold-deciduous forest with some evergreen needle leafed trees, MUC code 0222 at level 4). In Table LAND-P-6, the Difference/Error Matrix you find the matching in the left-hand column (the first row for MUC Code 0222). For sample number 1 on the Example MUC Classification Work Sheet (Table LAND-P-5), you determine that the validation data from the Land Cover Sample Sites (Table LAND-P-5-cell B) is mainly cold-deciduous forest with evergreen broad leafed trees, MUC code 0221. In Table LAND-P-6 the Difference/Error Matrix, from the cell with the identified Student Classification MUC code 0222, you move along the row (left-to-right) until you find the column with a label which matches the Validation Data MUC code 0221. In the cell at the intersection between the MUC code 0222 row and the MUC code 0221 column, (cell B1), you mark one tally and move to the next sample. In this way, the rows represent the areas of the map and the columns represent the validation data. The overall accuracy is calculated using the procedure illustrated in Table LAND-P-6.

It should be understood that collecting validation data (Land Cover Sample Sites) is a time consuming process; it may take numerous classes to put together enough data for a valid matrix. This is an excellent place within GLOBE to rely on a learning community to cooperate in accomplishing a protocol. Using Qualitative Land Cover Sample Sites will greatly speed up this process; however, scientifically, Quantitative Land Cover Sample Sites are preferred.

How to Tally Validation Data on a Difference/Error Matrix and Calculate Overall Accuracy

Refer to Tables LAND-P-5 and LAND-P-6 to help you understand the following procedures.

Step 1: Preparation

- ❑ It is important to remember not to look at what you, the student, labeled an area before going out to collect validation data for that same area. Knowing what the image

Table LAND-P-5: Example MUC Classification Data Work Sheet

Sample Number	Site Name	Student Classification on a Land Cover Map	Validation Data from Land Cover Sample Sites	√	X
1	Brown's Woods	A: Mainly cold-deciduous forest with some evergreen needle leafed trees (MUC code 0222)	B: Mainly cold-deciduous forest with evergreen broad leafed trees (MUC code 0221)		X
2	Smith State Park	C: Mainly evergreen wood-land with rounded crowns and needled leaves (MUC code 1121)	D: Mainly evergreen wood-land with rounded crowns and needled leaves (MUC code 1121)	√	
3	Appleby Farm	E: Pasture (MUC code 811)	F: Pasture (MUC code 811)	√	
4	Green's Woods	G: Mainly cold-deciduous forest with evergreen broad leafed trees (MUC code 0221)	H: Mainly cold-deciduous forest with evergreen broad leafed trees (MUC code 0221)	√	

Table LAND-P-6: Difference /Error Matrix Example

Validation Data

Map Classification

	MUC code 0222	MUC code 0221	MUC code 1121	MUC code 811	**Row Total**
MUC code 0222	**A1:**	B1: 1	C1:	D1:	E1: 1
MUC code 0221	**A2:**	B2: 1	C2:	D2:	E2: 1
MUC code 1121	**A3:**	B3:	C3: 1	D3:	E3: 1
MUC code 811	**A4:**	B4:	C4:	D4: 1	E4: 1
Column Total	**A5: 0**	B5: 2	C5: 1	D5: 1	E5: 4

$$\mathbf{E5} = \mathbf{A5} + \mathbf{B5} + \mathbf{C5} + \mathbf{D5} = \mathbf{E1} + \mathbf{E2} + \mathbf{E3} + \mathbf{E4}$$

(column total) = (row total)

$$\text{Overall Accuracy} = \frac{\mathbf{A1} + \mathbf{B2} + \mathbf{C3} + \mathbf{D4}}{\text{E5}} * 100 = (3/4) * 100 = 75\%$$

classification says an area is before collecting the validation data biases the collection. Therefore, validation data should be collected on the Data Work Sheet outlined in the Land Cover Sample Site Protocols and then the example Table LAND-P-5 should be created in the classroom after the data has been collected and recorded. Table LAND-P-5 can then be used as the input to create the difference/error matrix. A check is used to represent agreement between the student classification and the validation data while an X denotes a difference.

Step 2: Build an empty difference/error matrix

❑ Build an empty square matrix. There should be a column and row in the matrix for every MUC class that occurs in the validation data or on the portion of the land cover map that is being validated. Label each of the columns and rows of the matrix with one of these MUC classes. Be sure that the labels are in the same order starting from the upper left-hand corner going down and across. Be sure to include a right-hand column and a bottom row for totals

Step 3: Identify student classification from map for sample 1

❑ For a sample on your MUC Classification Work Sheet, look up the Student MUC Classification for the area of the land cover map in which this sample site is found.

Step 4: Find appropriate row in matrix for data

- ❑ Find the row in your matrix corresponding to the area of the map in which this land cover sample site is located.

Step 5: Identify MUC class from validation data for sample

- ❑ On your MUC Classification Work Sheet, look up the validation data MUC Classification for this sample site.

Step 6: Find appropriate cell in matrix for data and tally

- ❑ Move along this row from left to right to the box in the column labeled with the MUC class corresponding to that of the validation data. Mark one tally in this box.

Step 7: Repeat steps 3 through 6 for each sample

- ❑ Repeat this process for each sample on your MUC Classification Work Sheet. After you have completed tallying all of the samples, calculate the totals for each row and column. If the sum of the row totals does not equal the sum of the column totals, recheck your arithmetic.

Step 8: Calculate overall accuracy

- ❑ Sum the number of tallies in all the boxes on the major diagonal of the matrix (i.e. the boxes for which the row and column labels are the same) except the lower right-hand total box. Divide this sum by the total number of samples which is equal to the value in the lower right-hand box. Multiply this quotient by 100 to convert it to a percentage. Refer to the example in Table LAND-P-6.

Step 9: Interpret results

- ❑ Just as the cells along the major diagonal represent all the correct classifications or agreement between the student classification of the map and the validation data collected by students at Land Cover Sample Sites, the cells which are off the major diagonal represent incorrect classifications or the differences. Hence the name difference matrix or error matrix. This information can be used to identify MUC classes that were particularly difficult to classify, and also which MUC classes were confused with each other.

Figure LAND-P-17 presents a difference/error matrix for three broadly generalized land cover categories. This matrix is simply a cross-classification comparing the map categories to the validation data. In the places that agreement occurs, a tally is made along the major diagonal. Differences or errors are represented by the off-diagonal elements of the matrix. In addition to depicting the matrix as a 2 dimensional table, it can also be represented 3 dimensionally. In this case, it is easy to see that the more accurate the map, the bigger the blocks along the major diagonal.

Reporting the Data

Report all difference/error matrices to the GLOBE Student Data Base.

Figure LAND-P-17: A Difference/Error Matrix for Broad Land Cover Categories

Validation Data

Classified Data (Map)	F	W	U	Row Total
F	28	14	15	57
W	1	15	5	21
U	1	1	20	22
Column Total	30	30	40	100

Land Cover Categories

F = Forest

W = Water

U = Urban

Overall Accuracy = 63/100 = 63%

Producer's Accuracy

F = 28/30 = 93%

W = 15/30 = 50%

U = 20/40 = 50%

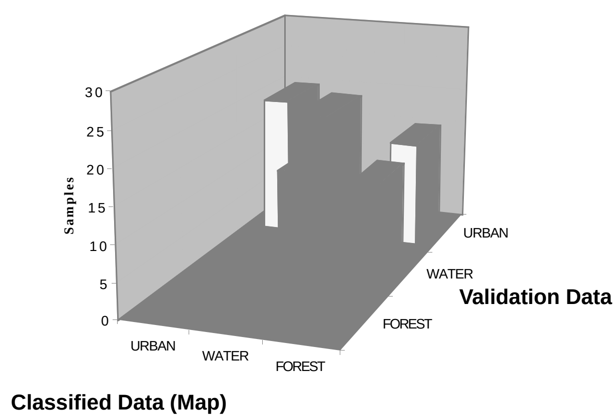
User's Accuracy

F = 28/57 = 49%

W = 15/21 = 71%

U = 20/22 = 91%

Figure LAND-P-18: A 3-D View of a Difference/Error Matrix



Learning Activities

Leaf Classification

Students make a collection of leaves and then discover how a hierarchical classification system is developed by sorting and organizing their leaves according to a set of labels and rules which they specify.

How Accurate Is it? Introducing the Difference/Error Matrix

Students learn how to evaluate the accuracy of a classification scheme.

What's the Difference?

Students learn how to evaluate the accuracy of a classification scheme.

Odyssey of the Eyes

These beginning, intermediate and advanced level activities will introduce students to modeling as it relates to remote sensing.

Some Like It Hot!

Students will learn about remote sensing, false-colored images and image resolution. This activity is divided into beginning, intermediate and advanced levels.

Discovery Area

This intermediate level activity will help students refine their understanding of remote sensing and mapping.

Site Seeing

Beginning and intermediate level activities introduce students to the concept of dynamic systems.

Seasonal Changes in Your Biology Study Site(s)

Students investigate seasonal changes by collecting data on spring bud-break and fall leave senescence.

Leaf Classification

Purpose

Students will learn to classify (sort) a group of objects into different groups (classes). Students will learn about hierarchical classification systems. These fundamental concepts will help students better understand the MUC scheme used in the GLOBE *Land Cover* and *Accuracy Assessment Protocols.*

Overview

Students will gather an assortment of leaves from the school. As a group, they will develop their own classification system for sorting leaves, and will learn that there are different ways to classify the same group of objects. This activity introduces the complexity of a "simple" task for which there are no truly correct answers.

Time

One class period

Level

All

Key Concepts

Classification helps us organize and understand the natural world.

A classification system is a set of labels and rules used to sort objects.

A hierarchical system has multiple levels of increasing detail.

Skills

Creating a classification scheme

Using the scheme to organize objects

Beginning: *Sorting* and *grouping* objects

Intermediate: *Using* labels and rules in *classifying* objects

Advanced: *Using* detailed labels and rules in *classifying* objects

Materials and Tools

A variety of different leaves

Chalk board or large paper for classification scheme outline

Preparation

Collect a variety of different leaves.

Prerequisites

None

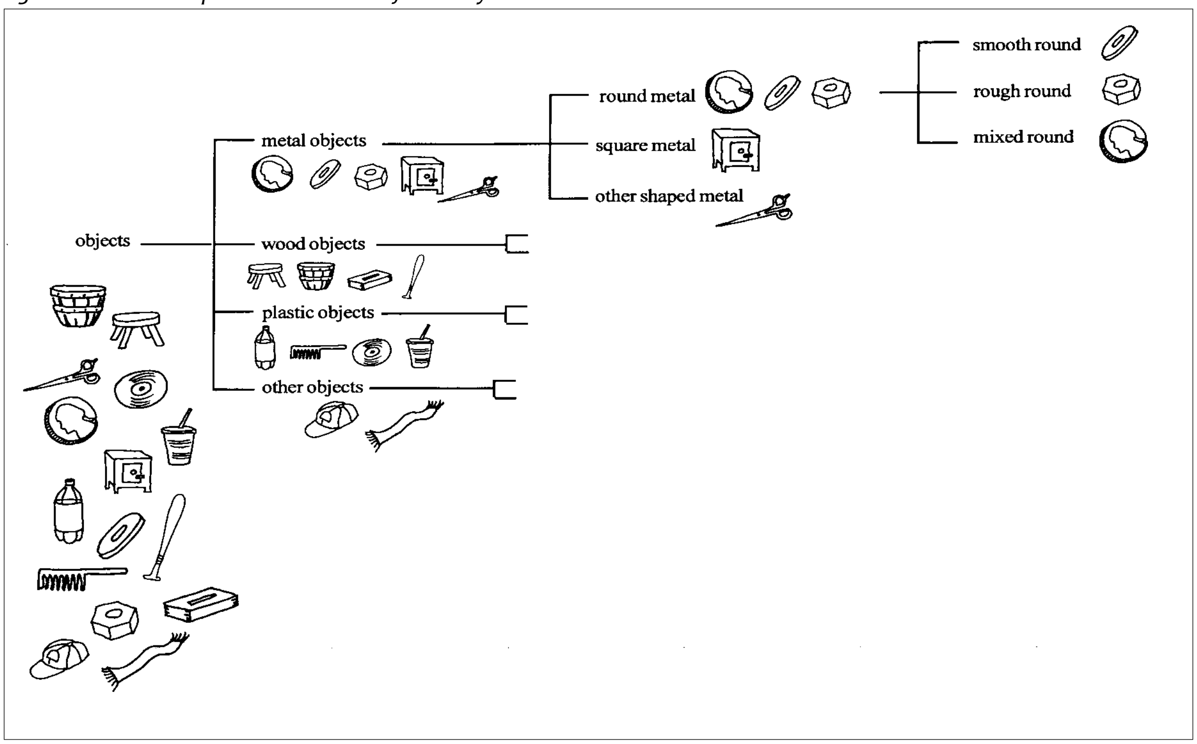
Background

Scientists classify many features of our environment such as clouds, soil types, or forest types. These classifications help us organize and understand the natural world. A *classification system* is an organized scheme for grouping objects into similar categories. There are two components to a classification system: *labels and rules*. The labels are the titles of the different classes in the classification system; the rules are the tests you apply to decide in which class to place an object. Well-defined labels and rules allow scientists to consistently describe and organize objects. For example, the Modified UNESCO Classification System used in the GLOBE protocols allows GLOBE participants to consistently describe the land cover at any point on earth using the same labels and rules as all the other GLOBE participants.

There are several key characteristics of all good classification systems. First, the classes must be *mutually exclusive* - that is, any object must have only one appropriate class in which it can be placed. If a classification system could place a leaf in either of two categories, then the classes are not mutually exclusive. Second, the classification system must be *totally exhaustive* - that is, there must be an appropriate class for all potential objects. This is frequently achieved by having a catch-all class such as "other". If you have a leaf for which there is no appropriate class, then the classification system is not totally exhaustive, and it must be modified, usually by adding at least one more class.

Finally, a classification system should be *hierarchical*. There should be multiple levels of increasing detail. At any level of detail, all the different classes should be able to "collapse" into the next (less detailed) level of the classification system. Figure LAND-L-1 is an example of a hierarchical classification system of objects to illustrate: level one classes are metal objects, wood objects, plastic objects, and objects of other materials; level two classes within metal objects are round metal objects, square metal objects, and other shaped metal objects; level three classes within square metal objects are smooth surfaces, rough surfaces, and mixed surfaces; and so on.

Figure LAND-L-1: Sample Hierarchical Classification System



What To Do and How To Do it

1. Gather a collection of leaves (and bunches of needles) to be sorted into groups - get as many, and as many varieties as possible. Even try to get brown (old) and green (fresh) leaves. Try to make sure there are several conifer and deciduous varieties as well as plant or shrub leaves. If you live in a grassland area, you could use grasses or other herbaceous ground cover.
2. Gather the class in a circle. In the center, on the floor or on a table, spread out all of the leaves.
3. Instruct the students that they have to sort (classify) all of the leaves into groups of similar types. Using a chalkboard to list suggestions, have the students suggest different characteristics that could be used for sorting the leaves. Discuss the difference between labels and rules. Discuss which characteristics are most important - or just have the students vote to decide the order of importance. They should realize that there is not necessarily one correct way. Classification systems are somewhat arbitrary, governed only by what we think makes sense. At the end of this step, you should have several characteristics, in hierarchical order of importance and generality, to be used for sorting the leaves.

Variation: Divide the class into groups and have each perform this step working independently. Then compare the classification systems and discuss the results.

4. Explain to the students that this hierarchical group of characteristics is a classification system. Scientists use classification systems to classify just about everything they encounter in the natural world: animals; trees; clouds; soils; and groups of vegetation associations, e.g., forest, desert, and meadow. Refer to the Accuracy Assessment pre-protocol learning activities for examples of bird and cloud classification.
5. Have the students sort the leaves using the chosen labels and decision rules. As the students sort the leaves, they may find that the classification system has to be modified or refined. This happens frequently in scientific projects. If there is time, students can use several different classification systems for sorting the leaves.

Discussion Questions

1. Why is it important that a classification system be exhaustive, mutually exclusive, and hierarchical?
2. How is it possible that there is no one "correct" classification system for leaves?
3. Do the user's objectives affect the classification system which would be used?
4. Is a more detailed classification system better?

Variations

You can use various assortments of natural or unnatural objects for this exercise. Many things work well. It is useful to use leaves especially with younger students, so that students are comfortable distinguishing conifer and deciduous leaves and needles from each other.

Student Assessment

Assuming that students have participated in an activity "debriefing" using the discussion questions above, they should be able to accomplish the following:

1. Describe the design of their classification system, including the basis for the labels they use to establish different classes of leaves.
2. List rules or decision criteria they use for assigning each leaf to its class.
3. Describe how they structured the hierarchical system.
4. Have classified all of the leaves they collected using their system.

Each level of learners (beginning, intermediate, advanced) is likely to explain their approach using increasingly complex or detailed information and criteria.

The ultimate measure of student's understanding of how classification systems are constructed and used will be the ease with which students are able to use the Modified UNESCO Classification System (MUC).

To determine whether students have grasped the concepts of developing a classification system have them review by answering the following questions:

1. What is a classification system?
2. What labels did you use to identify different classes of leaves?
3. What rules (criteria) did you use to assign each leaf to its class?
4. What are the levels of your classification system?
5. Are all of your leaves identified by assigning them to a class using the multiple layers of your system?

How Accurate Is It? Introducing the Difference/Error Matrix

Purpose

To quantitatively evaluate the accuracy of a classification

Overview

Students will sort birds into three possible classes: carnivores (meat eaters), herbivores (plant eaters), and omnivores (meat and plant eaters) based on the bird's beak. They will then compare their answers with a given set of validation data and generate a difference/error matrix. The students will then discuss how to improve their accuracy based on identifying specific mistakes they made as indicated by the difference/error matrix.

Time

One class period

Level

Intermediate to Advanced

Prerequisites

Basic ability to classify things

Fractions and percentages

Key Concepts

Classification helps us organize and understand the natural world.

In order for classification systems to be useful, we need to quantitatively determine their accuracy.

Criteria are used to define accuracy levels.

Skills

Classifying birds

Evaluating the accuracy of the classification

Improving the accuracy of the classification based on the evaluation

Analyzing data to understand the inter-relationships of a classification and its accuracy

Identifying decision criteria for a classification system

Collecting and *interpreting* validation data

Building and *analyzing* a difference/error matrix for accuracy assessment

Solving problems cooperatively to resolve accuracy issues

Materials and Tools

Master set of bird pictures

Master validation sheet

Overhead showing a sample bird classification work sheet

Set of bird pictures

Sample beak sketches

Classification Work Sheet

Difference/Error Matrix Work Sheet.

Preparation

Bird picture sets need to be reproduced without the answers on the back. Also student work sheets need to be reproduced for each group.

Background

Scientists classify many features of our environment, such as species of life, forest types, or soil types. These classifications are a fundamental mechanism for helping us to organize and to understand the natural world. There may be several different appropriate ways to classify a set of objects of interest. Two particular objects may be classified differently either because of error on the part of one or both of the classifiers, or simply because different classifying criteria were used. In any case, we need to know how much error is in our classification in order to use the information we have obtained with some confidence in its accuracy. Ultimately, the information generated by the classification of remotely sensed data will be used to make important decisions about global problems such as deforestation, global warming, and environmental degradation. It is very important that we not make these decisions based on information that is inaccurate.

A difference/error matrix is the basic tool used for accuracy assessment of remotely sensed data. It gives us a mechanism for generating a number rating the overall accuracy of a classification or map and provides information about the sources of error. This can focus our attention on those areas or classes that require it. We can use this information to improve the quality of our classification criteria, and to improve our skill at distinguishing those classes for which there is a lot of confusion.

References

Peterson's Field Guide to Birds

Audubon Field Guides

The Illustrated Encyclopedia of Birds: The Definitive Reference to Birds of the World. Consultant-in Chief Dr. C. Perrins. New York: Prentice Hall Press, 1990.

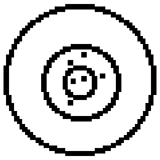
Check local resources for regional guides

Acknowledgment

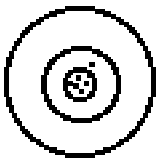
Art by Linda Isaacson

Key Terms and Concepts

accuracy: the degree of conformity to a standard or accepted value. Compare to precision.



The marks on this bull's-eye have high accuracy and low precision



The marks on this bull's-eye have high accuracy and high precision

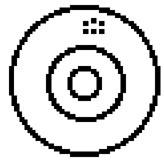
classification: taking a set or group of items and sorting them (classifying them) into well-defined and distinct subsets according to specific criteria. For example, taking a map and outlining areas of evergreen trees, deciduous trees, mixed evergreen and deciduous trees, and non-forest.

criteria: a decision rule. For example, if a forest stand has more than 50% evergreen needles in its canopy, the stand will be classified as evergreen. The preceding definition (e.g., more than 50% evergreen needles) is the *criteria*, the *category* or *class* is evergreen.

dataset: a group of values related to the same question being asked. These values will be analyzed together as a group. For example, the set of the heights of all students in this class would be one dataset.

difference/error matrix: (see the difference/error matrix on the work sheet at the end of this exercise) a table of numbers organized in rows and columns which compares a classification to validation data. The columns represent the validation data while the rows represent the classification generated by students. A difference/error matrix is a very effective way to represent accuracy. Correct and incorrect classifications can be compared for each category and used to improve the accuracy of the original classification.

precision: the closeness of several measures to each other. The repeatability of a measurement. This is a very important part of any scientific operation, but is different from accuracy.



The marks on this bull's-eye have high precision and low accuracy

validation data: data collected with a presumed high degree of accuracy. A classification of items (birds in this exercise) is compared to validation data: 1.) to improve the decision criteria for the classification 2.) to better understand the sources of error in the classification; and 3.) to assess the accuracy of the classification data.

Validation data is often collected to improve the classification of an image generated by some form of remote sensing (aerial photography or satellite imagery). Often the term "ground truth" is used in place of validation data, however, many scientists prefer the term reference or validation data. Data that is gathered on the ground always has some degree of error and thus does not represent the "truth".

Example

The following is an example of a filled in classification work sheet, difference/error matrix, and an overall accuracy calculation.

Table LAND-L-1: Sample Bird Classification Work Sheet

Bird Id#	Student Classification	Validation Data	✔ or x
1	Carnivore	Carnivore	✔
2	Omnivore	Carnivore	x
3	Herbivore	Herbivore	✔
4	Carnivore	Carnivore	✔
5	Herbivore	Herbivore	✔
6	Herbivore	Omnivore	x
7	Omnivore	Omnivore	✔
8	Carnivore	Carnivore	✔
9	Carnivore	Herbivore	x
10	Omnivore	Carnivore	x

Table LAND-L-2: Sample Difference/Error Matrix Work Sheet

Validation Data

Student Data	Carnivore	Herbivore	Omnivore	Row Total
Carnivore	A1. 3	B1. 1	C1. 0	D1. 4
Herbivore	A2. 0	B2. 2	C2. 1	D2. 3
Omnivore	A3. 2	B3. 0	C3. 1	D3. 3
Column Total	A4. 5	B4. 3	C4. 2	D4. 10

Note: Row and column totals should add up to the same number. Check with others in your group to make sure you counted correctly for each answer in the matrix.

$$\mathbf{D4 = \underbrace{(A4 + B4 + C4)}_{\text{(column total)}} = \underbrace{(D1 + D2 + D3)}_{\text{(row total)}}}$$

How to read this information:

Across row one (A1-D1) of this example, three carnivores were correctly identified by the students as carnivores, one herbivore was incorrectly classified as a carnivore and no omnivores were classified as carnivores.

Computing the Accuracy:

$$\text{Overall accuracy} = \frac{\text{sum of major diagonal (A1+B2+C3)}}{\text{total of entire matrix (D4)}}$$

Step 1: Sum the values in the boxes along the major diagonal (A1+B2+C3) shown in Table 4-13: Sample Difference/Error Matrix. This number is the total number of correct classifications. In this example there are six correct classifications out of ten total samples.

(3+2+1) = 6

Step 2: Divide the total number of correct classifications (A1+B2+C3) by the total number of samples (box D4).

6 divided by 10 = 0.6

Step 3: Multiply by 100 for the overall accuracy of the exercise:

0.6 times 100 = 60% accuracy

The calculation can be done for any of the individual categories as well (e.g., 3 out of 5 carnivores were classified correctly). The numbers off the major diagonal represent "incorrect" classifications. Each error or difference is an omission from the correct category and a commission (i.e., an erroneous addition) to the incorrect category.

If your answer is between:	**Your Level of Expertise is:**
0%-50%	Novice
51%-85%	Intermediate
86%-100%	Advanced

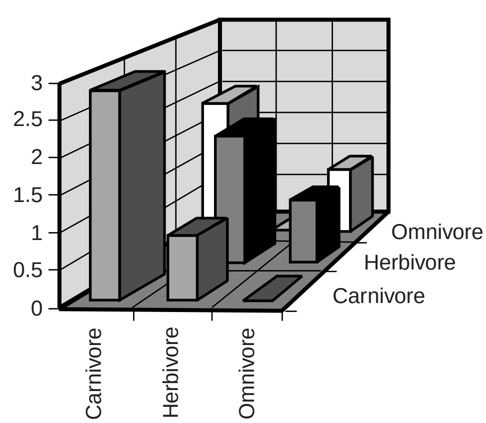
The class can also compare fractions (1/2 is less than 3/4, 3/4 is less than 9/10) instead of percentages.

Adaptations

1. A visual interpretation can be used instead of mathematically calculating the overall accuracy. Layout a 3 cell x 3 cell grid on a sheet of paper numbered like the cells in the difference/error matrix.

   Visually represent the number of birds in each box by either graphing or physically stacking blocks in the boxes. The tallest columns should be along the diagonal of the grid.
2. If the class has access to computer spreadsheets, a 3-D graph can be created to represent the answers. Figure LAND-L-2 shows the data from the example difference/error matrix graphed in a
   3-D format.
3. The activity may be modified by leading the activity for the whole group and creating one difference/error matrix on the black board.

Figure LAND-L-2: Difference/Error Matrix of Bird Classification Data



Source: GLOBE, 1996

What To Do and How To Do It

1. To prepare your students, discuss with them the following questions:
   - Why do we organize or sort objects into groups?
   - How do we sort these objects?
   - Name three examples of objects that are commonly sorted into groups.
2. Copy and distribute the student work sheets, the bird pictures, the bird beak sketches, the classification work sheet, and the difference error/matrix work sheet.
3. Have your students follow the instructions on the work sheets, to do the following steps:
   - Classifying pictures of birds into three categories.
   - Comparing answers with the reference data provided.
   - Generating a difference/error matrix using the results of the comparison.
4. After your students have completed this activity, discuss the results with your students by asking the following questions:
   - How did different students' results vary?
   - Why do students think this happened?
   - What other classifications might be compared using a difference/error matrix (e.g., maps identifying land cover for a specific location versus carefully checking the same location in person.

Student Activity Guide

Duplicate and distribute to students.

Overview

Scientists classify many features in our environment, such as species of life, forest types or rock types. These classifications, or categories, help us to organize and understand the natural world. In order for these classifications to be useful to scientists, we need to know how accurate they are. A difference/error matrix is the basic tool used to measure the accuracy of a classification procedure. This difference/error matrix also shows us where there was confusion or difficulty classifying certain classes.

In this activity you will:

- Classify pictures of birds into three categories
- Compare answers with the reference data provided
- Generate a difference/error matrix using the results of the comparison

When you have completed this activity, you will be able to:

- Classify birds as carnivores, herbivores or omnivores using given criteria
- Compare answers to a set of validation data and produce a difference/error matrix
- Identify categories with the most errors
- Evaluate the overall accuracy of the bird classification
- Understand the importance of the Difference/Error Matrix and how to use the information it provides

Materials

1. A set of 10 bird pictures
2. Sample beak type sketches
3. Classification and Difference/Error Matrix Work Sheets for Bird Classification

What To Do and How To Do It

In the following activity you will be classifying types of birds as:

C....carnivores (meat eaters)
H...herbivores (plant eaters)
O...omnivores (plant and meat eaters)

Examples of preferred foods:

Carnivores.......fish, meat, insects, worms, small mammals
Herbivores.......vegetation, seeds, nuts, and berries
Omnivores.......all of the above

The size and shape of the bird's beak will usually indicate its preferred food type. Many birds are opportunistic, however, and will supplement their preferred diet with a variety of foods when a scarcity of food requires it.

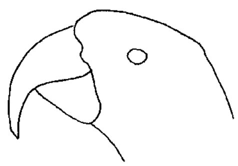
Figure LAND-L-3: Sample Beak Types

Duplicate and distribute to students.

Student Reference Sheet for Activity

Herbivore Beak Types

Finch Type: Heavy wedge shaped beaks are good for cracking nuts and seed



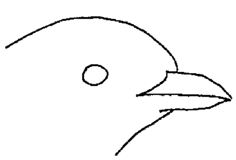
Parrot Type: Thick curved upper and lower beak are also for cracking nuts or tearing fruit apart. The upper beak as a sharp point and usually curves over the lower beak.

Carnivore Beak Types

Insect Eater Type: Long slender, slightly curved beaks are used to probe for insects and spiders in tree bark and soils

Meat Eater Type: Shorter than the insect eater, upper beak has a sharp curved overhanging tip and straight lower beak specialized for tearing meat.

Omnivore Beak Types



Jay Type: Wide, medium length beak is used for eating insects, fruit, seeds, and even carrion.

Thrush Type: Shorter and more slender than the Jay type, also for eating meat, plants, and insects.

Duplicate and distribute to students.

Bird Classification Work Sheet

Procedure

1. Look at each of the birds on the cards (numbered 1-10) and classify it as a carnivore, herbivore, or omnivore. Record each answer in the student classification column on the bird classification work sheet below.
2. Your teacher will provide the information to be recorded in the column labeled "validation data". Be sure to fill in this column accurately, this data will be needed to complete the difference/error matrix.
3. Look at all ten pairs and mark each matching pair with a check mark and each different (incorrect) pair with an "X" in the third column.

Table LAND-L-3: Bird Classification Work Sheet

Bird Id#	Student Classification	Validation Data	✔ or x
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

Duplicate and distribute to students.

Difference/Error Work Sheet for Bird Classification

4. Fill in the first row of the difference/error matrix by using the following directions:
   A. Count how many times your group matched a student classification of carnivore with a validation answer of carnivore. Place that number here _______________. Now place the same number in the box labeled A1 of the difference/error matrix.
   B. Count how many times your group matched a student classification of carnivore with a validation answer of herbivore. Place that number here _______________. Now place the same number in the box labeled B1 of the difference/error matrix.
   C. Count how many times your group matched a student classification of carnivore with a validation answer of omnivore. Place that number here _______________. Now place the same number in the box labeled C1 of the difference/error matrix.

Be sure to check with your teacher before continuing...

Repeat this process for each of the other categories filling in the remaining two rows.

Table LAND-L-4: Difference/Error Matrix for Bird Classification

Validation Data

Student Data		Carnivore	Herbivore	Omnivore	Row Total
	Carnivore	A1.	B1.	C1.	D1.
	Herbivore	A2.	B2.	C2.	D2.
	Omnivore	A3.	B3.	C3.	D3.
	Column Total	A4.	B4.	C4.	D4.

5. Sum the row totals, column totals and box D4.

Box D4 = A4 + B4 + C4 = D1 + D2 + D3
(column total) (row total)

The numbers in the outlined boxes (the major diagonal), are classified correctly. Go through the other boxes in the matrix to find any incorrect classifications. The difference/error matrix shows which categories are most difficult to identify. The numbers off the major diagonal represent "incorrect" classifications. Each error or difference is an omission from the correct category and a commission (i.e., an erroneous addition) to the incorrect category.

Which difference/error box has the largest number?

Duplicate and distribute to students.

Figure LAND-L-4: Calculating the Difference/Error Matrix

$$\text{Overall Accuracy} = \frac{(A1+B2+C3)}{D4} \times 100$$

$$\text{Overall Accuracy} = \frac{\boxed{A1} + \boxed{B2} + \boxed{C3}}{\boxed{D4}} \times 100 =$$

6. Calculate the overall accuracy as outlined on the sample work sheet.

If your answer is between:	**Your level is:**
0%-50%	Novice
51%-85%	Intermediate
86%-100%	Advanced

Follow up Discussion and Activities

1. Did you have difficulty correctly classifying a particular category. Why?
2. How could you reduce the number of errors next time?
3. What are some other ways to classify birds?
4. Do you have any suggestions for improving the classification criteria?
5. How did different students' results vary? Compare your difference/error matrix to other students' difference/error matrices to see who had the largest number of accurate answers and to see if other groups made mistakes classifying the same categories. What caused the mistakes?
6. What other measures can be used to evaluate data quality?

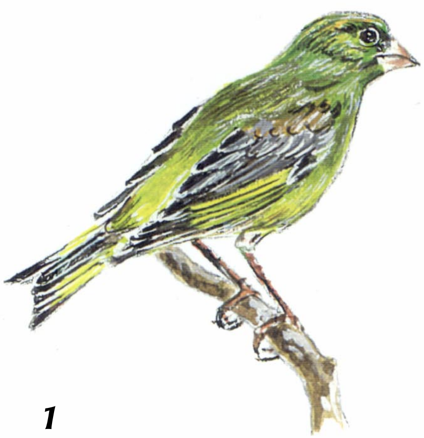
Further Investigations

1. Combine all the class data to create a class difference/error matrix. Calculate the overall accuracy of the class.
   Which do you think is more accurate, your matrix or the combined class results? Why?
2. Try to develop your own criteria for classifying a group of objects (for example, insects).

Duplicate and distribute to students.

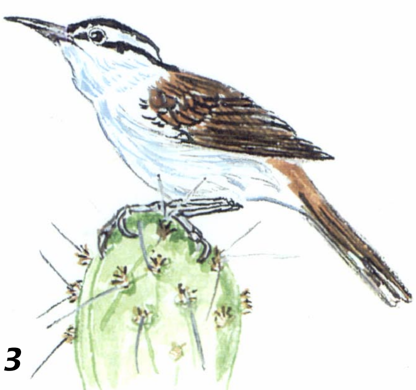
Table LAND-L-5: Bir d Classification V alidation Data Sheet

	Bird Name	Classification
1	Western Greenfinch	Herbivore
2	European Starling	Omnivore
3	Bicolored Wren	Carnivore
4	Rose-ringed Parakeet	Herbivore
5	Bru Bru Shrike	Carnivore
6	Clay Colored Robin	Omnivore
7	Pine Grosbeak	Herbivore
8	Eurasian Jay	Omnivore
9	Common Tree Creeper	Carnivore
10	Hermit Thrush	Omnivore



1

2



3

4

Art by Linda Isaacson

2. European Starling

(*Sturnus vulgaris*)

This bird (21 cm in size) lives in open woods, parks, and gardens in Europe and Western Asia, and has been introduced to North America, South America, Southern Australia and New Zealand. It eats both plants and animals.

Classification:

OMNIVORE

1. Western Greenfinch

(*Carduelis chloris*)

This bird (14.5 cm in size) lives in open woodland, bushes, and gardens in Europe, Northern Africa, Asia Minor, Middle East, and Central Asia. Its diet consists of nuts and seeds, especially sunflower seeds and peanuts.

Classification:

HERBIVORE

4. Rose-ringed Parakeet (*Psittacula krameri*)

This bird (41 cm in size) lives in woodlands and farmlands in Central Africa east to Uganda, India, Sri Lanka, and has been introduced to Middle and Far East, North America, England, Netherlands, Belgium, and West Germany. It eats grain or ripening fruit.

Classification:

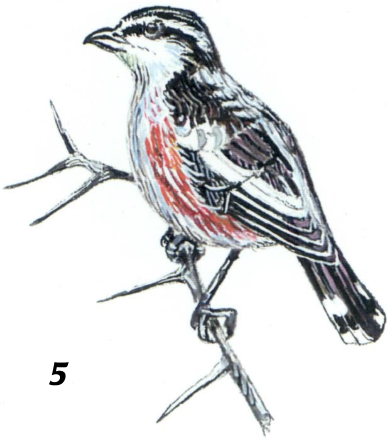
HERBIVORE

3. Bicolored Wren (*Campylorhynchus griseus*)

This bird (22 cm in size) lives in dry savanna, cactus scrub, and open woods in Colombia, Venezuela, Northern Brazil and Guyana. Its finds insects and insect eggs by peering and poking into crevices on the ground.

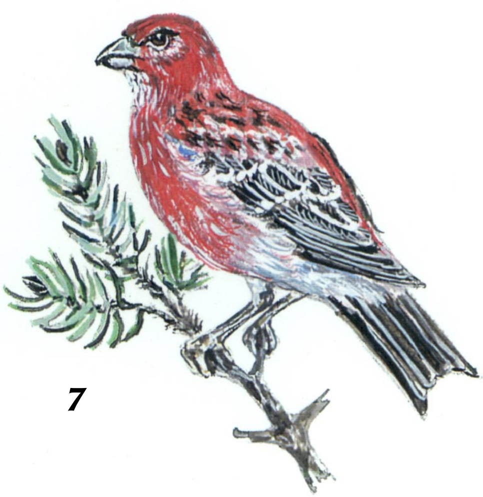
Classification:

CARNIVORE



5

6



7

8

Art by Linda Isaacson

6. Clay Colored Robin (*Turdus grayi*)

This bird (23-24 cm in size) lives in open woodland, woodland edge and clearings, usually near streams in Southeast Mexico, Central America, coastal Colombia. It eats insects, earthworms, slugs and lizards as well as fruit.

Classification:

OMNIVORE

5. Bru Bru Shrike

(*Nilaus afer*)

This bird (15 cm in size) lives in savanna woodland and sometimes the forest edge in tropical Africa. It eats insects and catches food on the wing.

Classification:

CARNIVORE

8. Eurasian Jay

(*Garrulus glandarius*)

This bird lives in oak woods, and open country in Western Europe, across Asia to Japan and Southeast Asia. It eats insects, beech nuts and acorns.

Classification:

OMNIVORE

7. Pine Grosbeak

(*Pinicola enucleator*)

This bird (20 cm in size) lives in the coniferous and scrub forests of North and West North America, North Scandinavia and Siberia. It eats berries and buds on the ground or in treetops.

Classification:

HERBIVORE

9

10

Art by Linda Isaacson

10. Hermit Thrush

(*Catharus guttatus*)

This bird (15-20 cm in size) lives in woodlands, forest edges and thickets in North and Central America. It eats insects, spiders, snails, earthworms and salamanders as well as fruits and seeds.

Classification:

OMNIVORE

9. Common Treecreeper

(*Certhia familiaris*)

This bird (12.5 cm in size) lives in woodlands particularly coniferous woodlands in Western Europe and Japan. It eats insects and insect eggs gleaned from tree bark.

Classification:

CARNIVORE

Reference: *The Illustrated Encyclopedia of Birds: The Definitive Reference to Birds of the World.* Consultant-in Chief Dr. C. Perrins. New York: Prentice Hall Press, 1990.

What's the Difference?

Purpose

To learn how to quantitatively evaluate the accuracy of a classification

Overview

Students will classify (sort) clouds into three possible classes: cirrus, stratus, and cumulus based on their knowledge from the *Cloud Identification Protocol*. They will then compare their answers with a given set of validation data and generate a difference/error matrix. The students will then discuss how to improve their accuracy based on identifying specific mistakes they made as indicated by the difference/error matrix.

Level

Intermediate and Advanced

Time

One class period

Key Concepts

Classification helps us organize and understand the natural world.

In order for classification systems to be useful, we need to quantitatively determine their accuracy.

Criteria are used to define accuracy levels.

Skills

Classifying clouds

Evaluating the accuracy of the classification

Improving the accuracy of the classification based on the evaluation

Analyzing data to understand the inter-relationships of a classification and its accuracy

Identifying decision criteria for a classification system

Collecting and *interpreting* validation data

Building and *analyzing* a difference/error matrix for accuracy assessment

Solving problems cooperatively to resolve accuracy issues

Materials and Tools

Sets of laminated cloud pictures

Answer key (validation data sheet)

Procedures for this activity

Classification Work Sheet

Difference/error Matrix Work Sheet.

Preparation

The student work sheets need to be reproduced for each group.

Prerequisites

An activity covering the basics of classification, experience with the GLOBE *Cloud Identification Protocol*, and the *How Accurate Is it? Introducing the Difference/Error Matrix Learning Activity*

Background

Scientists classify many features of our environment, such as species of life, forest types, or soil types. While these classifications are really arbitrary human impositions on the natural world, they are also a fundamental mechanism for helping us to organize and to understand the natural world. There may be several different appropriate ways to classify a set of objects of interest. Two particular objects may be classified differently either because of error on the part of one or both of the classifiers, or simply because different classifying criteria were used. In any case, we need to know how much error is in our classification in order to use the information we have obtained with some confidence in its accuracy. Ultimately, the information generated by the classification of remotely sensed data will be used to make important decisions about global problems such as deforestation, global warming, and environmental degradation. It is imperative that we not make these decisions based on information that is inaccurate.

A difference/error matrix is the basic tool used for accuracy assessment of remotely sensed data. Its value is that it not only gives us a mechanism for generating a numerical rating of the overall accuracy of a classification or map, but it also provides a tremendous amount of information about the sources of error. This can focus our attention on those areas or classes that require it. We can use this information to improve the quality of our classification criteria, and to improve our skill at distinguishing those classes for which there is a lot of confusion. The use of cloud classification as the basis for this activity will both build upon and strengthen students' cloud identification skills from the GLOBE climate protocol.

Key Terms and Concepts

See Key Terms and Concepts under *How Accurate Is It? Introducing the Difference/Error Matrix* .

Acknowledgment

Art by Linda Isaacson.

References

National Audubon Society Pocket Guide to Clouds and Storms. New York: Alfred A. Knopf, Inc, 1995

GLOBE Cloud Chart, 1996

You may want to make an overhead of the next page with the example Cloud Classification Work Sheet and Difference/Error Matrix. The instructions are on this page.

Tallying Procedure and Overall Accuracy Calculation

For the following procedures refer to the sheet marked “example”:

Step 1 For sample number 1 from the Cloud Classification Work Sheet (Table 21) determine the Student Classification cloud type (Table 21, cell A - Cirrus).

Step 2: In Table 22, the Difference/Error Matrix, find the matching student classification cloud type (cirrus) in the left-hand column.

Step 3: For sample number 1 from the Cloud Classification Work Sheet (Table 21), determine the Validation Data cloud type (Table 22, cell B - Stratus).

Step 4: In Table 22, the Difference/Error Matrix, from the cell with the identified Student Classification cloud type (cirrus), move along the row (left-to-right) until you find the category along top row which matches the Validation Data cloud type (Stratus). In the cell at the intersection between the cirrus row and the Stratus column (cell B3), tally one and move to the next sample. In this way, the rows represent the student data, and the columns represent the validation data.

Step 5: Move to sample 2 in the Cloud Classification Work Sheet and continue this process. After you have completed tallying all of the samples, you must calculate the overall accuracy.

Step 6: The total number of samples (cell D4) equals the row total (D1 + D2 + D3), which also equals the column total (A4 + B4 + C4). The total correct classifications equals the sum of the cells A1 + B2 + C3 (the major diagonal, bold-bordered cells). Divide the total correct, 1, by the total number of samples, 3. Multiply by 100 to get a percentage - 33%. This value represents the overall accuracy of the student classification.

Step 7: Just as the cells along the major diagonal represent all the “correct” classifications, the cells which are off the major diagonal represent “incorrect” classifications or differences. Hence the name difference matrix or error matrix. Each error or difference is also an *omission* from the MUC class in which it should have been classified, and a *commission* (i.e., erroneous addition) to the incorrect MUC class. This information can be used to identify cloud types that were particularly difficult to classify, and also which cloud types were confused with each other.

Table LAND-L-6: Example Cloud Classification Work Sheet

Sample Number	Photo Number	Student Classification	Validation Data	✔	X
1	3a	A: Cirrus	B: Stratus		X
2	3c	C: Stratus	D: Stratus	✔	
3	3d	E: Stratus	F: Cumulus		X

(See Validation Key, Table ________; and Figure _______:Cloud Classification Samples.)

Table LAND-L-7: Cloud Classification Difference/Error Matrix Example

Student Data

	Cumulus	Stratus	Cirrus	Row Total
Cumulus	A1:	B1:	C1:	D2: 0
Stratus	A2: 1	B2: 1	C2:	D2: 2
Cirrus	A3:	B3: 1	C3:	D3: 1
Column Total	A4: 1	B4: 2	C4: 0	D4: 3

Validation Data

D4 = A4 + B4 + C4 = D1 + D2 + D3

(column total) = (row total)

$$\text{OVERALL ACCURACY} = \frac{\text{A1 + B2 + C3}}{\text{D4}} \times 100 = (1/3) \times 100 = 33\%$$

What To Do and How To Do It

1. To prepare your students, discuss with them the following questions:
   - What is the difference/error between a classification category an a classification criteria?
   - Why is classification an important activity?
   - How does classification relate to mapping?
   - Why is it important for a map to be accurate?
2. Copy and distribute the student instructions, and the numbered cloud photos.
3. Have your students follow the instructions on the work sheets to do the following steps:
   - classify the clouds into categorized by type of cloud.
   - cross reference with the validation cloud types.
   - prepare the Difference/Error Matrix.
4. Discuss with your students how this activity relates to the *Accuracy Assessment Protocol.*

Duplicate and distribute to students.

Student Materials

Overview

Scientists classify many features in our environment such as species of life, forest types, or rock types. These classifications, or categories, help us to organize and understand the natural world. In order for these classifications to be useful for scientists, we need to know how accurate they are. A difference/error matrix is the basic tool used to measure the accuracy of a classification procedure. This difference/error matrix also shows us where there was confusion, or difficulty classifying certain classes.

In this activity, images of clouds will be classified into 3 clearly defined categories according to given criteria. Results of this classification will be compared with validation (reference) data by entry onto a chart. The accuracy of charted results will be tallied in a difference/error matrix.

When you have completed this activity, you will be able to:

- classify a set of items (images of clouds) into a well-defined classification scheme
- compare the classifications to a set of validation data to generate a difference/error matrix
- gain an understanding of the meaning of measurement accuracy and precision
- gain insight into some sources of error in scientific measurements.

Materials and Tools

A set of 20 cloud pictures
Copy of procedure with cloud type sketches and Difference/Error Matrix
Cloud Classification Work Sheet

What To Do and How To Do It

1. Carefully spread out the numbered cloud photos as provided and directed by your teacher. Twenty (20) will be classified in this exercise.
2. Using a Cloud Classification Work Sheet, classify all of the clouds in the dataset into three categories: cumulus, stratus, and cirrus.

   Note: Cloud types do not always fit exactly into in these three basic categories. For the purpose of this exercise, use only this simplified classification scheme. Some confusion may occur in the classification process. Accept this 'fuzziness' as part of the uncertainty in the activity. This uncertainty is part of the nature of science, any particular classification scheme never exactly matches the perceived state of the natural world.

Duplicate and distribute to students.

The criteria for the classes are as follows:

cumulus: detached clouds, generally dense and with sharp outlines, developing vertically in the form of rising mounds, domes or towers, of which the upper bulging part often resembles a cauliflower;

stratus: generally gray cloud layer with a fairly uniform base;

cirrus: detached clouds in the form of white, delicate filaments or white or mostly white patches or narrow bands. These clouds may look like horsetails.

3. Sort the clouds into three piles or columns (cumulus, stratus, and cirrus), leaving photos which are difficult to classify between the piles or columns. After classifying all the photos, return to the photos which were difficult to classify. Make a final determination of the appropriate class for each of these. If there is more than one type of cloud in a photo, you must select one dominant cloud type to classify the photo. The decision criteria for the dominant cloud type is whichever cloud type covers the greatest percentage of the sky in the photo. Check your classifications for each one of the twenty photos and record these in the Student Classification column on the Cloud Classification Work Sheet.
4. Your teacher will provide the validation cloud types to the class. You must record the validation cloud type for each photo in the Validation Data column on the Cloud Classification Work Sheet. A record of all the validation cloud types will be *necessary* to complete the exercise!
5. For each photo in which the Student Classification cloud type matches the Validation Data cloud type, put a check (÷) in the (X or ÷) column. For each photo which does not match, put an X in the (X or ÷) column.

Duplicate and distribute to students.

6. Tally the results from the match (X or ÷) column in the matrix using the following directions and the example:
   A. Using the Cloud Classification Work Sheet, count how many times your group matched a student classification of cumulus with a validation answer of cumulus. Place that number here __________. Now place the same answer in cell A1 in the Difference/Error Matrix below.
   B. Now count how many times your group matched a student classification of cumulus with a validation answer of stratus. Place that number here _______. Now place the answer in cell B1 below.
   C. Check with your teacher before going further!
   D. Fill in the rest of the Difference/Error Matrix following the same procedure.
   E. Double-check that every sample from the Cloud Classification Work Sheet has been tallied in the Difference/Error Matrix. Now, calculate the overall accuracy of your classification according to the formula at the bottom of this page.

Table LAND-L-8: Cloud Classification - Difference/Error Matrix Work Sheet

Validation Data

Student Data	Cumulus	Stratus	Cirrus	Row Total
Cumulus	A1:	B1:	C1:	D2:
Stratus	A2:	B2:	C2:	D2:
Cirrus	A3:	B3:	C3:	D3:
Column Total	A4:	B4:	C4:	D4:

D4 = A4 + B4 + C4 = D1 + D2 + D3

(column total) = (row total)

$$\text{Overall accuracy} = \frac{A1 + B2 + C3}{D4} \times 100$$

Overall accuracy = ____________________ x 100 =__________

Table LAND-L-9: Cloud Classification Work Sheet

Sample Number	Photo Number	Student Classification	Validation Data	✔	X
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					
17					
18					
19					
20					

Table LAND-L-10: Cloud Classification - V alidation Data Sheet

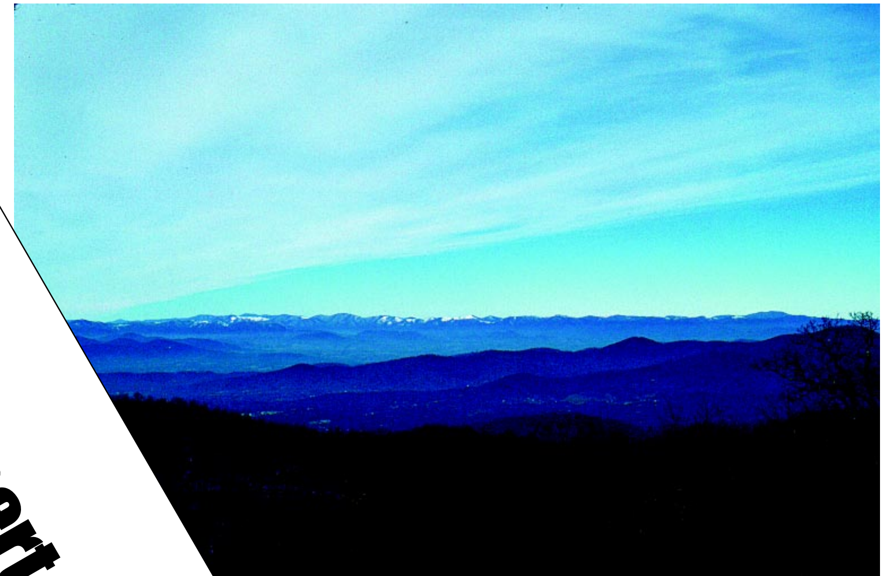
(Answer Key)

Photo #	Validation Data
1	Cirrocumulus
2	Cirrostratus
3	Cumulus
4	Stratus
5	Cirrus
6	Stratocumulus
7	Altocumulus
8	Altostratus
9	Nimbostratus
10	Cumulonimbus
11	Nimbostratus
12	Cumulonimbus
13	Altocumulus
14	Cirrostratus
15	Cirrostratus
16	Altocumulus
17	Nimbostratus
18	Cumulus
19	Altocumulus
20	Nimbostratus

Student accuracy measure:	**Level:**
0%-50%	Novice
51%75%	Intermediate
76%-100%	Advanced

Figure LAND-L-5 (photo 1)

Figure LAND-L-6 (photo 2)



Insert Color Page

Figure LAND-L-7 (photo 3)

hoto 4)

Source: Wayne M. Faas and Grant Goodge of the National Climatic Data Center, NOAA

Figure LAND-L-5 (photo 1)

Cirrocumulus: *high clouds with puffy, patchy appearance, with small spaces between clouds. Often form wave-like patterns.*

Figure LAND-L-6 (photo 2)

Cirrostratus: *high clouds, light gray or white, often thin with the sun or moon seen through them. Usually covers much of the sky.*

Figure LAND-L-7 (photo 3)

Cumulus: *low clouds. Clouds appear puffy, and look like cotton balls, popcorn or cauliflower.*

Figure LAND-L-8 (photo 4)

Stratus: *low clouds, light or dark gray and generally uniform in appearance and cover most of the sky. Fog is a stratus cloud.*

Figure LAND-L-9 (photo 5)

Figure LAND-L-10 (photo 6)

Figure LAND-L-11 (photo 7)

hoto 8)

Insert Color Page

Source: Wayne M. Faas and Grant Goodge of the National Climatic Data Center, NOAA

Figure LAND-L-9 (photo 5)

Cirrus: *high clouds, thin wispy and feathery, composed of ice crystals.*

Figure LAND-L-10 (photo 6)

Stratocumulus: *low clouds, with irregular masses of clouds, rolling or puffy in appearance, sometimes with space between the clouds.*

Figure LAND-L-11 (photo 7)

Altocumulus: *middle clouds with puffy, patchy appearance, usually with spaces between clouds.*

Figure LAND-L-12 (photo 8)

Altostratus: *middle clouds, light gray and uniform in appearance, generally covering most of the sky.*

Figure LAND-L-13 (photo 9)

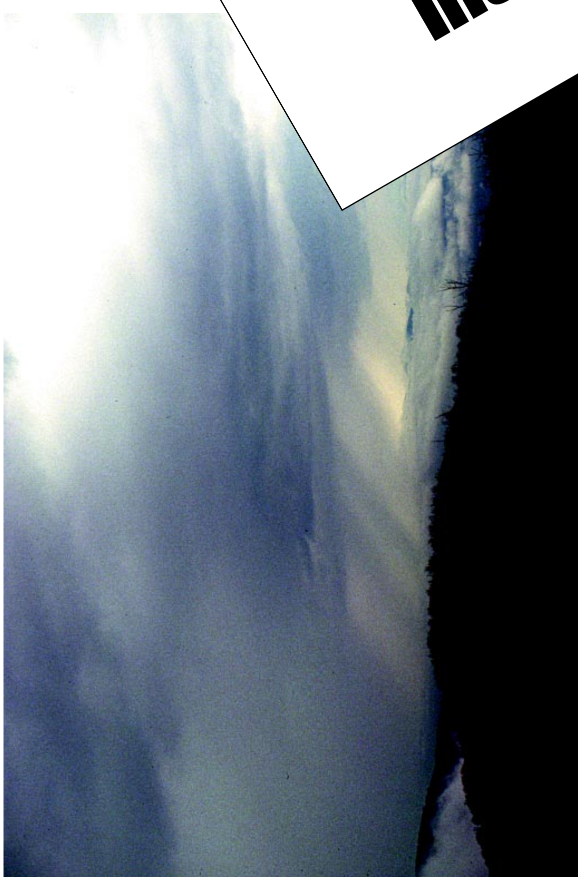


Figure LAND-L-14 (photo 10)

Figure LAND-L-15 (photo 11)

(photo 12)

Insert Color Page

Source: Wayne M. Faas and Grant Goodge of the National Climatic Data Center, NOAA

Figure LAND-L-14 (photo 10)

Cumulonimbus: *large clouds with dark bases and tall billowing towers. Can have sharp well defined edges or anvil shape at the top. Precipitation can obscure the base of the clouds. Can be accompanied by thunder.*

Figure LAND-L-13 (photo 9)

Nimbostratus: *low and middle dark gray clouds with precipitation falling from them. Bases are diffuse and difficult to determine because of falling precipitation.*

Figure LAND-L-16 (photo 12)

Cumulonimbus: *large clouds with dark bases and tall billowing towers. Can have sharp well defined edges or anvil shape at the top. Precipitation can obscure the base of the clouds. Can be accompanied by thunder.*

Figure LAND-L-15 (photo 11)

Nimbostratus: *low and middle dark gray clouds with precipitation falling from them. Bases are diffuse and difficult to determine because of falling precipitation.*

Figure LAND-L-17 (photo 13)

Figure LAND-L-18 (photo 14)

Insert Color Page

Figure LAND-L-19 (photo 15)

to 16)

Source: Wayne M. Faas and Grant Goodge of the National Climatic Data Center, NOAA

Figure LAND-L-18 (photo 14)

Cirrostratus: *high clouds, light gray or white, often thin with the sun or moon seen through them. Usually covers much of the sky.*

Figure LAND-L-17 (photo 13)

Altocumulus: *middle clouds with puffy, patchy appearance, usually with spaces between clouds.*

Figure LAND-L-20 (photo 16)

Altocumulus: *middle clouds with puffy, patchy appearance, usually with spaces between clouds.*

Figure LAND-L-19 (photo 15)

Cirrostratus: *high clouds, light gray or white, often thin with the sun or moon seen through them. Usually covers much of the sky.*

Figure LAND-L-21 (photo 17)

Figure LAND-L-22 (photo 18)

Figure LAND-L-23 (photo 19)

hoto 20)

Insert Color Page

Source: Wayne M. Faas and Grant Goodge of the National Climatic Data Center, NOAA

Figure LAND-L-21 (photo 17)

Nimbostratus: *low and middle dark gray clouds with precipitation falling from them. Bases are diffuse and difficult to determine because of falling precipitation.*

Figure LAND-L-22 (photo 18)

Cumulus: *low clouds. Clouds appear puffy, and look like cotton balls, popcorn or cauliflower.*

Figure LAND-L-23 (photo 19)

Altocumulus: *middle clouds with puffy, patchy appearance, usually with spaces between clouds.*

Figure LAND-L-24 (photo 20)

Nimbostratus: *low and middle dark gray clouds with precipitation falling from them. Bases are diffuse and difficult to determine because of falling precipitation.*

Odyssey of the Eyes

Beginning Level

Purpose

To familiarize students with the concept of modeling as it is related to remote sensing

Overview

In *Odyssey of the Eyes,* students will create a 3-D model of an area and develop a classification system for the land forms in their model. They will use their eyes as remote sensors and view the model from a variety of heights. The eyes will journey from very close to as far away as a satellite. Each time the student will create a map of the image they see. The maps can then be used to answer certain questions about the environment.

Time

Three to four class periods

Level

Beginning

Key Concepts

A map is a symbolic representation of a certain land area.

The field of view is how large an area your eye or a camera's eye can perceive.

The field of view increases the higher the eye is relative to the ground.

Skills

Modeling a landscape

Drawing the landscape from various perspectives

Materials and Tools

Paper towel or toilet paper tubes

A variety of objects to make the models (either teacher or student supplied).

Glue

Tape

Ruler

Preparation

Gather all materials prior to the building of the model.

Prerequisites

The students should be briefed on some very basic components about maps and models such as map keys and symbols.

Note: This activity presents concepts similar to those in steps 8, 9, and 10 of the *Relative and Absolute Directions Learning Activity* in the *GPS Investigation.*

Background

Maps are the most common model to represent the Earths' surface. The concepts of mapping and modeling are important in order for students' to understand the remote sensing protocols. For example, the satellite images that the students will view during the protocols are models of the Earth taken from satellites.

As a satellite revolves around the Earth, it takes pictures with a sensor that is sensitive to a variety of different wavelengths. One of the main wavelengths sensed is thermal radiation. The sensor reads the amount of heat being radiated and makes a picture out of the different values. In this activity students themselves will be acting as remote sensors of thermal radiation.

Although students may not know it, they have a great deal of experience with remote sensing. Anytime they observe something without touching it they are actually using their eyes, ears, nose, and skin surface to remotely sense that object. We may think of remote sensing as work that is only done by satellites, yet there are many instruments that are used to remotely sense objects. Your students may have experience in photography or in using a microscope. Both of these instruments give us information that we would not be able to access if we attempted to observe an object with our own, limited, senses.

The satellite images students will use in the protocols are made up of tiny squares, each square contains information about a certain land cover area. We call these photos digital. The tiny squares seen on these pictures are called pixels. Some images have pixels that represent a large area on the ground and others have pixels that represent smaller areas.

Scientists who study land cover use a variety of aerial photography and satellite images dependent on the purpose of their study. The GLOBE scientists are interested in analyzing the satellite photos to determine land cover types and land use changes over time.

In the remote sensing protocol, we are creating a thematic map of a 15 km x 15 km area with your school near the center. The information on the image you receive has been accumulated from a satellite. Your students will be classifying the land cover types with the use of the computer and also conducting ground verification of the resulting image. It is important for them to understand the concepts of modeling and remote sensing if they are to have a clear understanding of where this information comes from and the significance of it.

Resources: (Optional)

Looking Down, Jenkins, Steve, Hutton Houghton Mifflin, NY, 1995, 0-395-72665-4

View from the Air, Lindberg, R., Viking, NY, 1995, 0-670-84660-0

Mouse Views, McMillan, B., Holiday House, NY, 1995, 0-8234-1132-x

What To Do and How To Do It

Part 1: Building and V iewing the Model

1. Students form groups and write a plan for building a model of an area, real or imagined. The school yard is a popular choice, however, the design of the model should be student generated. Students should list materials necessary and draw a proposed picture of their model. See Odyssey of the Eye's registration form found after *Odyssey of the Eyes: Advanced Level.*
2. Students will need two to three class periods to build their models.
3. Students will now use their eyes to view the model through a paper towel tube from four different views. This will give students an opportunity to view a change in resolution and a change in field of view. Have students record their observations on Odyssey of the Eyes Observation Form found after *Odyssey of the Eyes: Advanced Level.*
   a. Mouse View — Observe the model from the side. Draw and label the map.
   b. Bee's View — Observe from 10 cm above the model. Draw and label the map.
   c. Bird's Eye View — Observe from desk level. Draw and label the map.
   d. Satellite View — Observe from a second story window or stairwell. Draw and label the map.

Discussion questions

1. Are there any visual differences between the Bee's View and the Mouse's View? What are they?
   Note: Young elementary school children often have more difficulty with the concept of "top view." Some extra time may be needed here. See resource list for suggested resources.
2. Compare your four drawings. Which view would be the most useful if you were:
   a. An eagle looking for a mouse?
   b. Deciding where to build a mall?
   c. Looking for animal tracks?

d. Studying the extent of deforestation or reforestation?
e. Finding a lost child in the woods?
f. Seeing how much of the forests of your area have been damaged by pollution?
g. Looking for a lost pin?

3. What are the advantages of using satellites to view the Earth? Are there any disadvantages?

Part 2: Making a symbolic map of the model

1. For each land cover item in the model (roads, rocks, playground equipment, pond, river, grass, houses, etc.), have students pick a symbol to represent it. List the land cover items with their symbol in the Odyssey of the Eyes Symbolic Map Data Sheet found after *Odyssey of the Eyes: Advanced Level.*
2. Use the symbols to create a map of this area. Draw the map on the Symbolic Map Data Sheet found after *Odyssey of the Eyes: Advanced Level.*
3. Student groups exchange symbolic maps, decipher the maps, and write a fictional story about an event that could occur within the depicted environment.

Discussion questions

1. If you were asked to make a map of your neighborhood would you prefer to draw a true to life map or a map using symbols? Support your answer.
2. Research map types and the purpose for each map type.

Odyssey of the Eyes
Intermediate Level

Purpose

To familiarize students with the concept of modeling as it is related to remote sensing and to introduce students to the process of digitizing pictures similar to the ones produced by a satellite's remote sensing equipment

Overview

In this intermediate level activity, *Odyssey of The Eyes* students will use the symbolic map created in the beginning activity to produce a digitized photo similar to the ones produced by a satellite's remote sensing equipment. As they perform the activity they will begin to see why ground verification of satellite data is necessary in order for scientists to create accurate models of the Earth's systems.

Time

Three to four class periods

Level

Intermediate

Key Concepts

Objects in a remotely sensed image are interpreted and digitized into a code based upon the object's reflectance of bands of light.

The image codes are relayed through a satellite dish to a computer for storage or enhancement.

Image display is accomplished by conversion of stored data to a user-defined color-coded image.

Skills

Observing an image
Interpreting an image
Classifying an image
Digitizing an image
Coloring an image

Note: This activity presents concepts similar to those in steps 8, 9, and 10 of the *Relative and Absolute Directions Learning Activity* in the *GPS Investigation*.

Materials and Tools

Graph paper
Pencils
Plastic overlay with grid
Image of the Panda Bear
Colored pencils

Preparation

Assemble the materials.

Demonstrate the process of digitizing to the class before you have students work with partners.

Prerequisites

Students should be briefed on the process by which satellites receive their information and relay it to computer.

The beginning activity is necessary for the completion of this activity.

What To Do and How To Do It

Part 1: How Digitized Pictures Are Made

Students will learn how satellites and computers communicate with each other. One student will serve as the satellite and the other will represent the computer. Using a black and white image, the satellite will scan the image translating it into a digitized code. The computer will translate the numeric code reproducing the image.

1. Students work in pairs. One serves as the satellite and the other represents the computer. The satellite places the plastic overlay over the black and white of the Panda Bear and scans the image one box at a time, starting at the left hand corner of the image. The satellite calls out a number code for each box to the computer.
2. The satellite will interpret each square according to the following guidelines:
   - If a box is white the satellite interprets the message as a "1" and the computer writes that number in the code.
   - If a box is black the satellite interprets the message as a "2" and the computer writes that number in the code.
   - If a box is neither all black nor all white the satellite must make a decision as to the best possible choice, "1" or "2". The satellite communicates that number to the computer and the computer writes it down in the code.
   - The satellite indicates the beginning and end of each scan line with a "0".
3. Using a pencil, the student representing the computer translates the digital code onto the graph paper creating a satellite image.

   Note: See the digital code in the advanced level of this activity for an example. Additional practice can be had using student generated color pictures and different size grids.

Part 2: Making a Digitized Map

1. Supply each group with a plastic grid overlay. Have the students place this grid over their symbolic map from the beginning activity. They will now have to create a color and number code for the land cover items. They are to place the data on the Odyssey of the Eyes Digitized Data Sheet (found after *Odyssey of the Eyes: Advanced Level*).
2. Assign each land form on the symbolic map a color and a number. Record this on the Digitized Data Sheet.

Ex.	buildings	1	blue
	trees	2	green

3. Scan each line of the symbolic map matching each square with a number. Record the numbers on the data chart. Begin and end each scan line with a "0". Review the guidelines in part one of this activity for further assistance. You have created a digital code for your symbolic map.
4. Using the digitized code, select the matching colors and reproduce the map as a digitized image on a piece of graph paper.

Discussion Questions

1. How different are the proportions of land cover types as compared to their symbolic map?
2. How different are the proportions of land cover types as compared to their original model?
3. Compare and contrast maps produced by different groups:

   How do you know the maps are accurate?

   What happens to land cover types that are small in area when you draw a symbolic map or digitize an image?

   How do these changes affect what type and amount of land cover you see?

Note: Ground verification is what you are doing in some of the protocols. It is checking what is actually on the ground compared to what is represented by a satellite image or a model.

Odyssey of the Eyes Advanced Level

Overall Purpose

To familiarize students with the concept of modeling as it is related to remote sensing

Advanced Level Purpose

In this advanced level activity, students exchange the digitized versions of their map with students in another school or classroom. Each group of students recreates the original image's cover types.

Overview

The advanced level of *Odyssey of the Eyes* demonstrates how a satellite sensor relates information to the computer. The students translate their maps into digital code and send it to another class room for translation into a color map. The connection between remote sensing technology, computer imagery and land cover assessment should be solidified at this point.

Time

Three to four class periods

Level

Advanced

Key Concepts

Objects in a remotely sensed image is interpreted and digitized based upon the object's reflectance of bands of light.

The image codes are relayed through a satellite dish to a computer for storage or enhancement.

Image display is accomplished by conversion of stored data to a user-defined color-coded image.

Skills

Observing an image

Interpreting an image

Classifying an image

Interpreting color codes for an image

Note: This activity presents concepts similar to those in steps 8, 9, and 10 of the *Relative and Absolute Directions Learning Activity* in the *GPS Investigation.*

Materials and Tools

Internet (optional)

Graph paper

Colored pencils

Digitized map produced from Part 2 of *Odyssey of the Eyes: Intermediate Level*

Computer Skills

Preparation

Assemble the materials.

Students will exchange digitized versions of their map with students in another school or classroom so a classroom or a school needs to be contacted in advance.

Prerequisites

Students should be briefed on the process by which satellites receive their information and relay it to computer.

The beginning level activity is necessary for the completion of this activity.

The students need to complete the Intermediate level activity.

What To Do and How To Do It

1. In the previous activity *Odyssey of the Eyes: Intermediate Level*, your students translated their map models into a digitized code. Type this digitized code into a word processor. Use a “0” to begin and end each line of the map. Allow the numbers to “word wrap” on the screen so that the map pattern is not visible in the message.

   example:

   011112200111133002464340024644400255655004444444001111220011113300111133001

   11122001111330011113300246434002464440025565500444444400111122001111330024643

   4002464440025565500246434002464440025565500444444400111122002556550044444440011

   1122001111330011113300111122001111330011113300246434002464440025565500444444400111122

2. Include the key to translate from codes to colors. (See Odyssey of the Eyes Digitized Data Sheet as filled in during the Intermediate Level activity.)

   Example:

   1 violet

   2 indigo

   3 green

   4 yellow

   5 orange

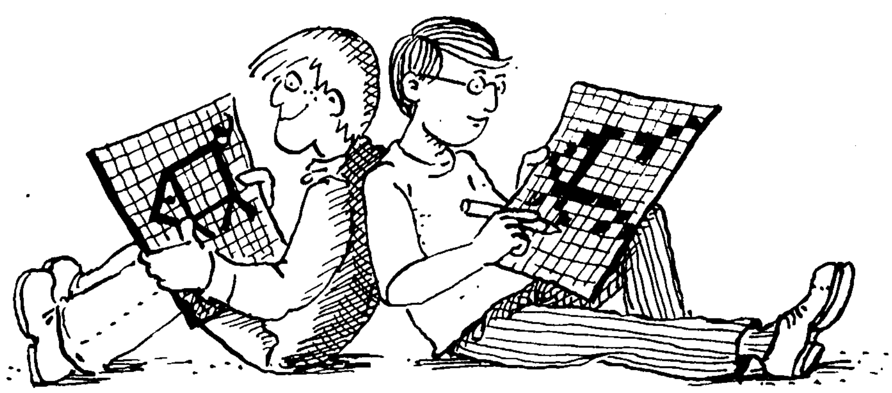
   6 red

3. Students in another class or school will receive the code and translate the code into a color map, producing a false color image. The completed maps can be returned to the sending school for verification.

Note: This exchange can be done on the Internet, by exchanging disks between schools or classes, or just by exchanging hard copies of the information.

Discussion Questions

1. What is the most dominant land covers on your false color image? To what geographical region do you think this area would belong?
2. Can you recreate a sketch of a map or a model of the area?



Source: Jan Smolík, 1996, TEREZA, Association for Environmental Education, Czech Republic

Odyssey of the Eyes
Names of Group Members:
Date:

Registration Form

Description and Diagram of Proposed Model

Materials Needed: Provided By:

Figure LAND-L-25: Observation of the Model - Odyssey of the Eyes

Odyssey of the Eyes **Observations of the Model**

NAME:

DATE:

Airplane View

Satellite's View

Figure LAND-L-26: Observations of the Model - Odyssey of the Eyes

Odyssey of the Eyes

Observations of the Model

NAME:

DATE:

Bee's Eye View

Bird's Eye View

Odyssey of the Eyes

NAME:

DATE:

Symbolic Map Data Sheet

LAND COVER KEY

Land cover item	Symbol
Road	Checked areas
Trees	Squares

1.
2.
3.
4.
5.
6.
7.

SYMBOLIC MAP

Including dimensions of model in centimeters (Length and width)

Odyssey of the Eyes

NAME:

DATE:

Digitized Data Sheet

Color and Number Code Key

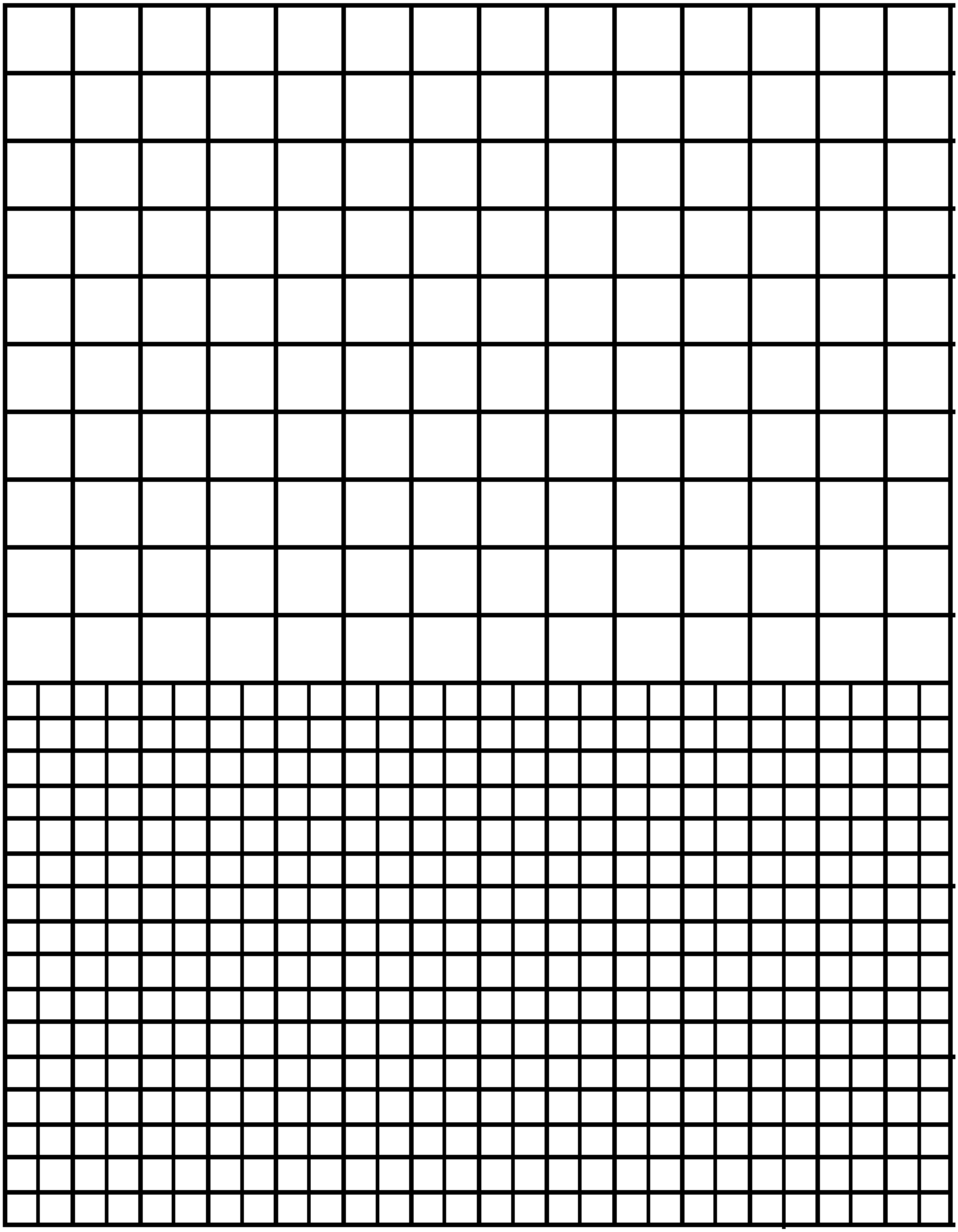
Land cover	Symbol	Number	Digitizing Color

Digitized Code

Use a 0 to indicate the beginning and ending of each scan line.

0_____ _____ _____ _____ _____ _____ _____ _____ 0
0_____ _____ _____ _____ _____ _____ _____ _____ 0
0_____ _____ _____ _____ _____ _____ _____ _____ 0
0_____ _____ _____ _____ _____ _____ _____ _____ 0
0_____ _____ _____ _____ _____ _____ _____ _____ 0
0_____ _____ _____ _____ _____ _____ _____ _____ 0
0_____ _____ _____ _____ _____ _____ _____ _____ 0
0_____ _____ _____ _____ _____ _____ _____ _____ 0
0_____ _____ _____ _____ _____ _____ _____ _____ 0

Figure LAND-L-27: Grid - Odyssey of the Eyes



Figur e LAND-L-28: T eddy Bear - Odyssey of the Eyes

Some Like it Hot!
Beginning Level

Purpose

To introduce students to the concepts of remote sensing and false colored images. Students create a map based upon temperature, using their hands as remote sensors. The challenge for the students in the project is to determine the location in a given area where an ice cube would melt the fastest and the location where an ice cube would last the longest.

Overview

As a satellite revolves around the Earth it takes pictures with a camera that is sensitive to a variety of different wavelengths. One of the main wave lengths sensed is thermal radiation. The sensor reads the amount of heat being radiated and makes a picture out of the different values. In this activity your students will use their hands as thermal sensors and explore an outside area with a variety of different land cover forms. The students will record the different values on a map of the area, just as a satellite does. When the students are done they will have a thermal map of their area.

Time

Three to five class periods

Level

Beginning

Prerequisites

Prior experience with field sketching is helpful.

A sunny day

Key Concepts

Orbiting satellites take photographs with cameras that are sensitive to a variety of different wavelengths.

One of the main wavelengths sensed is thermal radiation. The sensor reads the amount of heat being radiated and makes a picture out of the different values.

When students observe something without touching it they are actually using their eyes, ears, nose, and skin surface to remotely sense that object.

Skills

Observing a given area

Predicting the area that would melt an ice cube the fastest

Testing their predictions

Comparing different areas for thermal radiance

Mapping a thermal image

Materials and Tools

Ruler

Blank paper

Rope or string

Prism (optional)

Preparation

Classroom setup of bowls of hot water, ice, towels

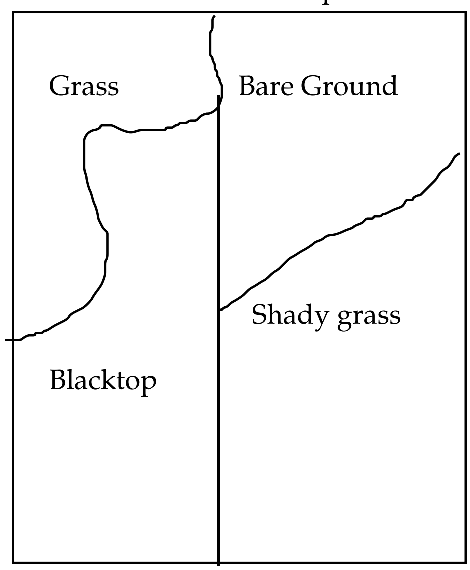
Ice cubes each made from two teaspoons of water

Confine or rope off area of approximately 5 - 10 meter square that contains a variety of land cover types. For example, an area may include blacktop, grass, and bare ground.

What To Do and How To Do It

1. Students should be placed in teams of two. Explain to the students that in a couple of days, they will be taken outside and given an ice cube. They will either be asked to find a location within a given area where they think the ice cube will melt the fastest or a location where they think their ice cube will be protected from melting.
2. Before exploring the outside area, the teacher sets up three to six examples in the classroom (bowl of ice, hot water, warm towel, area of tile floor). Students use their hands cupped downward to determine the relative temperature of each item. (Hands should not touch the item, they are remote sensors). Can they tell the differences between the examples if their eyes are closed?
3. This part of the activity is initiated outdoors in a confined or roped off area (approximate size 5-10 m square). Students will draw a field sketch of the square. On another piece of paper, the students should list the land covers they observe on site. The students should also draw a 12" ruler sized rectangle space reserved on the cover type listings. The teacher asks the class to make a list (or drawings in list form) of no more than 6 different land covers they observe. Some examples are rocks, asphalt, gravel, cut grass, long grass, shady grass, and sand. On the field sketch, the students should record a title for the project, date, time, location, compass directions, weather conditions, and team member names.
4. The students return to the site the following day with their list of land covers and use their hands, as practiced in the classroom, to measure the relative temperature of each land cover type and record this information next to each type of land cover listed so the information is arranged in some way from hottest to coolest.
5. Back in the classroom, the students divide the color rectangle on their key into boxes to represent the number of classes they observed and listed on site (see sample recording sheet). The teacher leads a class discussion over which colors will be used to represent the classes from hot to cold. Exploring and using the colors of the light spectrum as shown by the sun shining through a prism (if available) is suggested for setting color sequence. The teacher records the color sequence for the class to use. They use this sequence to color in the color boxes on the rectangle. (This box is the temperature key for the false colored image). From this chart, the students then complete the false coloring on their maps, coloring the land covers to match the information on the temperature scale.

Figure LAND-L-29: Sample Recording Sheet



Key

Land Cover	Color Rectangle
rocks	
gravel	
cut grass	
shady grass	
sand	
Blacktop	

6. In preparation for this part of the activity, the teacher makes ice cubes using two teaspoons of water. Ice cubes are taken out just prior to the activity and are wrapped in aluminum foil and placed in a cooler. The coin is tossed to determine whether they will have the challenge of melting the ice cube quickly or protecting the ice cube from melting. Each student team consults their map and chooses the location which best fits their challenge. The class is taken outdoors and each team is given an ice cube (covered with aluminum). They go to the chosen location, and upon a signal from the teacher, place the ice cube (minus the foil) down on the land cover. Upon giving the signal to begin, the teacher starts to record the time. When a students calls out “finished” the teacher gives a time, which the students records on a piece of paper. Students also record their selected location.
7. The teacher makes a table similar to the one below for students to display their results.
   The teacher writes the lowest minute time recorded and then asks the students who had between 1:00 and 1:29, for example, to place their results in the table. The process is repeated until all the data is recorded. A class discussion of the data follows and a new class temperature sensor map is created, showing the actual results of the ice cube activity. (This new map is an essential component for follow-up activities).

Acknowledgement: This is a revised version of the activity *Making an Icy Decision,* created by Lou Lambert for Gaia Crossroads, 1995.

Figure LAND-L-30: Some Like It Hot - Data Table

Group					
Time (min)	:00-:29	:30-:59	1:00-1:29	1:30-1:59	2:00-2:29

Some Like It Hot!
Intermediate Level

Purpose

To introduce students to the concepts of remote sensing and false colored images and to demonstrate exactly how a sensor displays heat sensing information in satellite photos and computer images

Overview

The students will use a thermometer to measure the heat radiating from the land cover types measured at the beginning level. They will recreate the thermal sensing map using a color code to depict thermal variations.

Time

Two to three class periods

Level

Intermediate

Key Concepts

Orbiting satellites take photographs with cameras that are sensitive to a variety of different wavelengths.

One of the main wavelengths sensed is thermal radiation or heat reflectance. The sensor reads the amount of heat being radiated and makes a picture out of the different values.

When students observe something without touching it, they are actually using their eyes, ears, nose, and skin surface to remotely sense that object.

Skills

Observing a given area

Measuring different land types with a thermometer

Comparing different areas for thermal radiance

Mapping a thermal image

Materials and Tools

Ruler

Blank paper

Rope or string

Small thermometer

Heavy paper cup

Wire coat hanger

Preparation

A confined or roped off area of approximately 5-10 meter square that contains a variety of land cover types. For example, an area may include blacktop, grass, and bare ground.

Assemble the thermometer apparatus; however, if time permits, it may be constructed by students.

Prerequisites

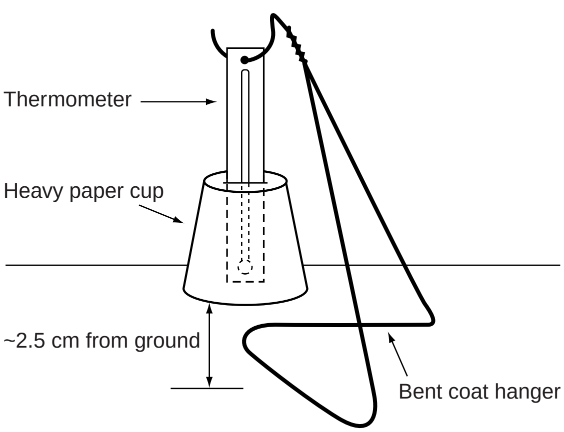
The beginning level activity is required.

The students need to know how to read a thermometer.

What To Do and How To Do It

1. Construct an infrared detector as shown in the illustration in Figure LAND-L-31: Thermometer Apparatus. This device is intended to measure the heat coming off an object and not from the air above. The paper cup works as a barrier to surrounding radiation. Look at the temperature gradients on the thermometer, assign colors to each range. For example, 0-5 = violet, 6-10=light blue, 11-15=aqua etc. until all degrees (in Celsius) are accounted for. These should be recorded in the Some Like It Hot Temperature Sheet found after *Some Like It Hot! Advanced Level.*

Figure LAND-L-31: Thermometer Apparatus



2. Using the thermometer apparatus, have the students measure the temperature coming from the same objects that they first measured with their hands in the beginning activity. Record the object temperature and appropriate color from the Some Like It Hot Temperature Sheet.
3. Staying in groups of two, the students go back out to the roped off area from the beginning activity and measure each land cover's temperature reflectance. Record the data and assign each cover type a color from the completed code on the Some Like It Hot Temperature Sheet.
4. Draw a map of the area. Label the temperature of each cover type and color the area with the appropriate color. On this map, the students should record the date, time, location and compass directions. Title this map, Temperature Sensor Map.

Discussion Questions

1. Compare the maps from the beginning activity and this activity. What are the differences?
2. By adding a temperature gradient how has the amount of color in the picture changed? Were there more or less total colors?
3. Are there any areas that were the same color on the heat sensor map that were different colors on the temperature sensor map? Why did this happen? If this did not happen on their map, the students should hypothesize why this could happen.
4. How close to the actual temperature reading were the students when they used their hands as heat sensors? The accuracy of the instrument in the beginning activity was their hands. Were some hands more sensitive than other students' hands?

Some Like it Hot! Advanced Level

Purpose

To introduce students to the concepts of remote sensing and false colored images. Students will produce false color images of an area of their choice. By creating two images with different grid size, they will understand differences in image resolution.

Overview

The advanced level of *Some Like It Hot!* is designed to demonstrate how a satellite sensor reads information. The students will make a grid and use it to measure the thermal reflectance of the land cover visible within the squares of the grid. The end product will be a thermal map created in pixel form.

Time

Three to five class periods

Level

Advanced

Key Concepts

Orbiting satellites take photographs with cameras that are sensitive to a variety of different wavelengths.

One of the main wavelengths sensed is thermal radiation or heat reflectance. The sensor reads the amount of heat being radiated and makes a picture out of the different values.

When students observe something without touching it they are actually using their eyes, ears, nose, and skin surface to remotely sense that object.

Skills

Observing a given area

Measuring different land types with a thermometer

Comparing different areas for thermal radiance

Mapping a thermal image

Materials and Tools

Meter sticks

String

Tape

Paper cup thermometer apparatus from intermediate activity

Preparation

A premade grid as a demo would be useful. See Some Like It Hot Thermal Sensing Grid Sheet for example.

Prerequisites

A prerequisite for this activity is the intermediate activity.

What To Do and How To Do It

1. Students work in groups of three or four to construct a large grid. They use four meter sticks taped together for the outer frame. They create the grid by taping string across the width at the 20 cm intervals and then taping string across the length at 20 cm intervals. See the diagram below.
2. The student groups go outside and find an area that contains a variety of land cover types within a square meter. An example might be the edge of the blacktop where grass and sand are showing, or rocks or ice etc. The students draw and label the area.
3. The students place the grid over the area they sketched. In each square of the grid, they measure the temperature with the paper cup thermometer apparatus as in the Intermediate activity. They record their findings on the Some like It Hot! Thermal Sensing Grid Sheet found at the end of this activity.
4. In the classroom, they color in the grid using the color key developed in the intermediate activity. They have developed a thermal sensing map like the satellite images they use.

Part 2

1. Repeat the experiment with a finer grid, every 10 cm.
2. How does the change in grid size affect the map? Scientists refer to this change in grid size as change in resolution. As the resolution becomes finer, more and more specific information is displayed. Different resolutions are needed for different types of inquiry.

2a. Students compare both images within the group (20 cm and 10 cm)
- Which image has the most identifiable picture?
- Which image would be most useful for land cover assessment over a large area?
- Which image would be most useful for a land cover assessment over a small area?

2b. Students trade images with another group.
- Can they tell where that area is outside?
- What kinds of land cover items might be there?
- Which image gives them the best clues?

2c. Students compare images with the whole class. They discuss the value of thermal sensing to the world. As a possible extension, they can research some of the ways that thermal sensing is used.

What To Do Next

Predicting Snow Melt Patter ns

Students use their temperature sensor map to predict a pattern of snow melt at the end of winter.

1. Explain to the students that the information they generated about the relative temperatures of land covers may help them predict the pattern of snow melt in their area. Review the data they collected during the temperature sensor map activity. Have them predict where the snow will melt the fastest in the spring and record those ideas and their reasons for later discussion.
2. Divide the teams into groups. Each team is assigned to a particular land cover within the site studied for the temperature sensor map activity. As spring nears, the students make daily trips to their location and record their observations.
3. As the snow melts to ground level, the students report land cover sightings. The sequence of land covers which become visible are recorded.
4. After all the data are recorded, the information is compared with the ice cube activity information gathered during the Beginning activity and any anomalies are explained by the students. Comparisons can be simplified by plotting observations onto wax paper or acetate and overlaying this plot on the original thermal map.

Some Like It Hot!

Name:

Date:

Temperature Sheet

Chart 1

	Range	Color
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

	Range	Color
11.		
12.		
13.		
14.		
15.		
16.		
17.		
18.		
19.		
20.		

Chart 2

	Object	Temperature	Color
1.			
2.			
3.			
4.			
5.			
6.			

Chart 3

	Land Cover	Temperature	Color
1.			
2.			
3.			
4.			
5.			
6.			

Table LAND-L-15: Thermal Sensing Grid - Some Like It Hot

Some Like It Hot

Name of Group:

Date:

Thermal Sensing Grid

What To Do Next

Predicting Patter ns of Seed Ger mination

Students use their temperature sensor map to predict a pattern of seed germination in the spring.

1. Explain to the students that the information they generated about the relative temperatures of land covers may help them predict where seed sprouts may first appear in the spring. Review the data they collected during the temperature sensor map activity. Have them predict where they think sprouts will first appear in the spring and record those ideas and their reasons for later discussion.
2. Divide the teams into groups. Each team is assigned to a particular land cover within the site studied for the temperature sensor map activity. As spring nears, the students make daily trips top their location and record their observations.
3. As the snow melts to ground level, the students report vegetation sightings. The location of the first sprouts are recorded. Students use field guides to assist in the identification of the types of vegetation reported.
4. After all the data are recorded, the information is compared with the ice cube activity information gathered during the Beginning activity and any anomalies are explained by the students. Comparisons can be simplified by plotting observations onto wax paper or acetate and overlaying this plot on the original thermal map.

Discovery Area Intermediate Level

Purpose

To use land cover maps to solve problems

Overview

Students will work to determine the location of a hospital while inflicting the least impact on the environment. They will utilize the unsupervised classified image from the remote sensing protocol to make their analysis and decision. The format of a town meeting will serve as the presentation of group work and for the overall class decision as to where to build the new hospital.

Time

Two to four class periods

Level

Intermediate

Key Concepts

Humans have an impact on the amount and type of land cover types.

Animals and plants are affected when land cover types change.

Humans need to be aware of the impact of land developments.

Skills

Analyzing different scenarios that change the land cover types of their areas

Predicting how the changes will affect the living organisms dependent upon that cover type

Evaluating solutions to various scenarios

Presenting their development plans to the class

Materials and Tools

A hard copy of the students' land cover map from the remote sensing protocols

Prerequisites

Students should have completed the remote sensing protocol.

Knowledge of the terms dominant, subdominant, rare, and isolated land cover types

Group presentation skills

What To Do and How To Do It

1. Divide the class into groups of three or four and discuss with your students what the land cover types are shown on the unsupervised clustered map. Have them list them in a chart like the one below.

a. Dominant	b. Subdominant	c. Rare or Isolated
1.	1.	1.
2.	2.	2.
3.	3.	3.
4.	4.	4.

2. Within the class thoroughly discuss each of the land cover areas. Pay close attention to living as well as non-living constituents. Have groups decide the three most desirable locations for a hospital, including parking lots and roads.

3. Using the chart, the students compare the land cover areas. How will the proposed development affect the plants and animals listed?
4. The students discuss the options with their group and narrow their decision to one.
5. The students construct a presentation board.
   - They enlarge the original classified image so that the land cover areas are easily recognizable.
   - Place the hospital, road, and parking lots that will be part of the development on the classified image basing the size on other buildings in the image.
6. The students prepare a presentation for the class. The presentation will take the form of a town meeting. Students will role-play local citizens and vote on the best place for placement of the hospital. Each presentation will be intended to persuade class mates that the team has picked the best spot.
7. After viewing all the other presentations, the students indicate which location they liked best and why.
8. After voting on an area, is there agreement with the class decision? Why or why not? Could there be more than one answer?

Site Seeing
Beginning Level

Purpose
The overall purpose of these pre-protocol activities is to introduce students to the concept of a system. The supporting concepts are boundaries, inputs, outputs, and feedback loops. The concept of a system will help students understand why they are conducting the biometry measurements on the 30 x 30 m Biology Study Site.

Overview
Students will investigate the environment of their 30 m x 30 m Biology Study Site. The students will use simple observational techniques to quantify and qualify their observations. The intention is that students will become curious about their system.

Purpose
The beginning activity will help students determine that a system's boundaries are often delineated depending upon the question the scientist wants to answer.

Time
Two or three class periods

Level
Beginning

Key Concepts
Your 30 m x 30 m Biology Study Site can be considered a system.

Your system contains certain elements within it such as trees, water, soil, rocks, and animals.

Your system has inputs such as sun's energy, water, carbon dioxide, oxygen, dust.

Your system has outputs such as water, carbon dioxide, oxygen, and heat.

Skills
Observing your system

Drawing your system

Interpreting maps as a data source

Materials and Tools
Paper

Colored pencils or crayons

Compasses

30 m x 30 m Biology Study Site sketch sheet

Camera

Preparation
The 30 m x 30 m Biology Study Site should be laid out.

Prerequisites
Students should understand why they are conducting the *Biometry Protocol* on this site.

Students should know how to use a compass.

Background
Scientists investigate natural systems for a variety of reasons. A *system* is any collection of *things* that have some influence on one another and appear to constitute a unified whole. The things can be almost anything, including objects, organisms, machines, ideas, numbers, or organizations. The question a scientist wants to answer often times determines the boundaries of the system. For example, an ecologist might want to study an entire ecosystem type such as wetlands to determine the amount of acreage still left in the world, or a specific species of wetland plant might be studied to experiment with different restoration techniques. Or a scientist might want to study one type of cell in a wetland plant to determine the plant's sensitivity to certain kinds

of pollution. These studies would consider completely different factors determined by the scale of the study.

In the biometry protocols, we are looking at a certain system (30 m x 30 m Biology Study Site) for changes over time. These include changes in the growth rate of trees and the times of leaf drop and budding. By collecting data over many years, we can see if the data are consistent over time or if there is variation. To understand the data, students need to be familiar with the variety of factors affecting a system in order to understand the change. If they know what is coming in and out of the system and the basic processing of incoming materials within the system they will be able to see patterns that will help them make generalizations and predictions. For example, water comes into a forested system in the form of rain. Some of the water is stored in the trees and is used in growth. Some is released into the atmosphere. Some stays on the surface. Some percolates into the ground to join the water table.

Data variation could indicate changes in either the input, output, or the cycles that process matter and energy. In a series of drought years, the growth of the trees may be stunted due to the lack of water, stress, production, or fitness. Consistent temperature rises could cause a longer growing season resulting in an increase in production. This may be evident in leaves being on the trees longer or the trees increasing in size at a greater rate during those years, as seen in the rings or tree height. The data your class collect will help your students and the GLOBE scientists understand the system around them.

What To Do and How To Do It

1. Ask the students to sit with a piece of paper and a pencil in front of them. The students should close their eyes and imagine their perfect place in the whole world (e.g. beach forest, next to a fire, in a candy store). Give them a minute to imagine this image. Have them draw their special place on paper. How many of the students imagined a natural area for their special place?
2. Visit the center of your 30 m x 30 m Biology Study Site. Why did the class choose this size and shape study site?
   Answer the following questions for your 30 x 30 m Biology Study Site.
   a. What are the natural boundaries of this system?
   b. What do you see, smell, feel, hear?
   c. Is it wet/dry, warm/cool?
   d. Is there a lot of sunlight hitting the ground?
   e. How many different plants and animals live there?
   f. How many objects are non-living? Are they natural or man-made?
   g. What would your system look like at night?
   h. How would your system change in the different seasons?
3. Staying in the center of your site, ask the students to stand and draw each boundary – North, South, East, and West. These will be side views. Encourage them to be observant and draw details. Have your students save these diagrams in their GLOBE Science Notebooks.
   Note: You can have the students use the 30 m x 30 m Biology Study Site sketch work sheet to draw the site. Save the box in the middle of the work sheet for the micro sketch in step 4.
4. In order to obtain an increased knowledge of the Biology Study Site, have the students lay out on the ground a 1/3m x 1/3m square made of string. Have them draw what they observe within the square.

Have them answer questions a through h in number 2 above. What questions could they study within this square (or system) that they couldn't in the 30 m x 30 m Biology Study Site? How did changing the boundaries change what they saw?

5. Have the students take a soil sample from their individual plots with an auger, trowel, or shovel. Try to get at least 15 cm down into the soil and place it in a plastic sandwich bag. In the classroom, have the students observe the soil with the unaided eye and a 30X microscope. Now what parts do you see? Are there living things here or parts of living things?
6. From the center point, take a picture of each directional view. Once the pictures are developed, have the students compare their sketched views with the photographs. Have they drawn enough detail in their sketches to identify which picture corresponds with each compass direction? Are there parts of the system that they missed?

   Note: You can use the 30 m x 30 m Biology Study Site Sketch Work Sheet. The middle box can be use for the students' drawing.

Discussion Questions

1. What kinds of questions were asked when they changed the boundary of their system?
2. How does what happens in your neighbors square influence what happens in yours?
3. What is above your square and what is below it?
4. Does what is above and below affect your square in any way?
5. Generally what enters and leaves your system? Sunlight? Water? Seeds? Nuts? Animals?

Site Seeing Intermediate Level

Purpose

To introduce students to the concept of a system. The supporting concepts are boundaries, inputs, outputs, and feedback loops. The concept of a system will help students understand why they are conducting the biometry measurements on the 30 x 30 m Biology Study Site. Students investigate the idea that every dynamic system has energy and matter. Inputs and outputs will vary depending upon the physical components of the site, the plant and animal life, the determined boundaries or scale of the study and the season of the year.

Overview

The intermediate level of Site Seeing builds upon the concepts presented in the beginning level. The class will travel to several different study sites including their 30 x 30 m Biology Study Site. At each site, students will explore a larger variety of system inputs and outputs, and will use more complex methods of data acquisition and analysis. The students will use the data from each site to compare and contrast the inputs and outputs of the environments.

Time

Three class periods

Level

Intermediate

Key Concepts

System boundaries will differ depending upon the question you are asking.

Systems contain certain elements such as trees, water, soil, rocks, and animals.

Systems have inputs such as sun's energy, water, carbon dioxide, oxygen, dust.

Systems have outputs such as water, carbon dioxide, oxygen, and heat.

Skills

Observing the components of the system and the inputs and outputs of the system

Measuring inputs and outputs of the system

Collecting data from the system

Interpreting the data collected about the various systems studied

Materials and Tools

String

30 x 30 m Biology Study Site

Thermometers

Rain gauges

Plastic sandwich bags

GLOBE Science Notebooks

Biology Field Site Work Sheet

Beaufort Scale Work Sheet

Heavy paper cup

Paper

Preparation

Use string to mark the borders of the 30 m x 30 m Biology Study Site.

Collect the data listed below at three different sites within your GLOBE Study Site– an open place such as a field or playground, near open water, and your Biology Study Site. Plan to visit the sites on the same day or on different days at about the same time.

Obtain necessary permission to visit the chosen sites, and check them for any safety hazards. Arrange for parents or other volunteers to accompany students to the sites.

You can use the Site Seeing Biology Field Site work sheet for students to record the data. Divide the class into three teams composed. Students should take the materials listed above and proceed with their missions at all three sites as follows.

Prerequisites

The rationale for the biometry protocol measurements on their 30 m x 30 m Biology Study Site.

The Beginning activity is recommended. If not used, students should understand the concept of system boundaries.

What To Do and How To Do It

1. Temperature – Ask the teams to measure each site's temperature at ground level, 2.5 cm deep in the soil, and at 0.5 m above the ground. To get the temperature of the soil below ground, carefully insert the tip of the thermometer into the ground. To get the temperature at or above ground level, you should insert the thermometer through a hole in the bottom of an upside-down heavy paper cup. The cup acts as a shield around the tip of the thermometer so that direct sunlight and other extraneous sources of heat do not cause inaccurate readings. The thermometer should be remain in one location until the temperature does not vary for 1-2 minutes.
2. Precipitation– What is the amount of rain during the last growing season? If you don't use the rain gauge from GLOBE, you can get the information from a meteorologist. A high school could use the GLOBE soil moisture of the area. Has it rained lately? What evidence is there – lakes, streams, water retainment areas, puddles?

   Have the students place a plastic sandwich bag over some living green leaves. Leave in place overnight. How much moisture is in the bag? Where did it come from? Where is it going?
3. Sunlight – When the sun is shining, look around your study site for signs of sunlight on the trees and on the ground. How much sunlight reaches the top of the trees? How much is reaching the ground? If sunlight is being absorbed by the plant, what happens to the sunlight? Is it being reflected (that means the leaves would be shiny and reflective like aluminum foil)?

   Note: Students will think that plants get their food from the soil and will not think the sun is used to make food during photosynthesis. They will think that sun helps plants to grow, but not sure how or why. Question students on how plants use sunlight in their life cycle?
4. Wind – How much wind is blowing in the sites? Are the leaves shaking in the breeze? Is the wind strong enough to bend small branches? Large branches? Have the students use a piece of paper as a temporary wind sock. See the Beaufort Scale Work Sheet. One student can hold the paper away from the body, while the others observe whether it hangs straight down or blows out at an angle. Have the students use the compass to determine from which direction the wind seems to be blowing.
5. Animal Life – Ask the teams to note the various kinds of animals at each site (insects, birds, reptiles, fish, frogs, or tadpoles). Students should record evidence of animals such as scat, tracks, burrows, or chewed leaves. Estimate the population of each animal type. Which is the most dominant?
6. Plant Life – Ask the teams to observe the various types of plants at each site (large trees, small trees, shrubs, small plants, grasses). Suggest that they record the most common types of plants found in each location. Estimate the population of each plant type? Which is the most dominant?
7. After the teams have had sufficient time to investigate each site, have them report their findings and share what they have learned. After listening to each other's reports, the class can complete a large composite class chart. Use this composite chart as a basis for discussing differences between the locations and interactions the students observe among the various elements.

Discussion Questions

1. How do the various sites differ in numbers or diversity of species of animals and plants? How are they different?
2. Which site had the highest air temperature? The lowest? The most wind? The least wind?
3. What relationship does light seem to have with air temperature? With soil moisture? With plants?
4. Which of the six variables studied seems most important for determining the character of the environment at each site? What makes you think so?
5. What are the inputs to the various systems? Which factors are outputs? Which of the six elements stays within the system? They can draw a picture or a flow chart of their sites.
6. Have students draw diagrams of their systems or make up a story about their system tracing the path of the sun through the system.

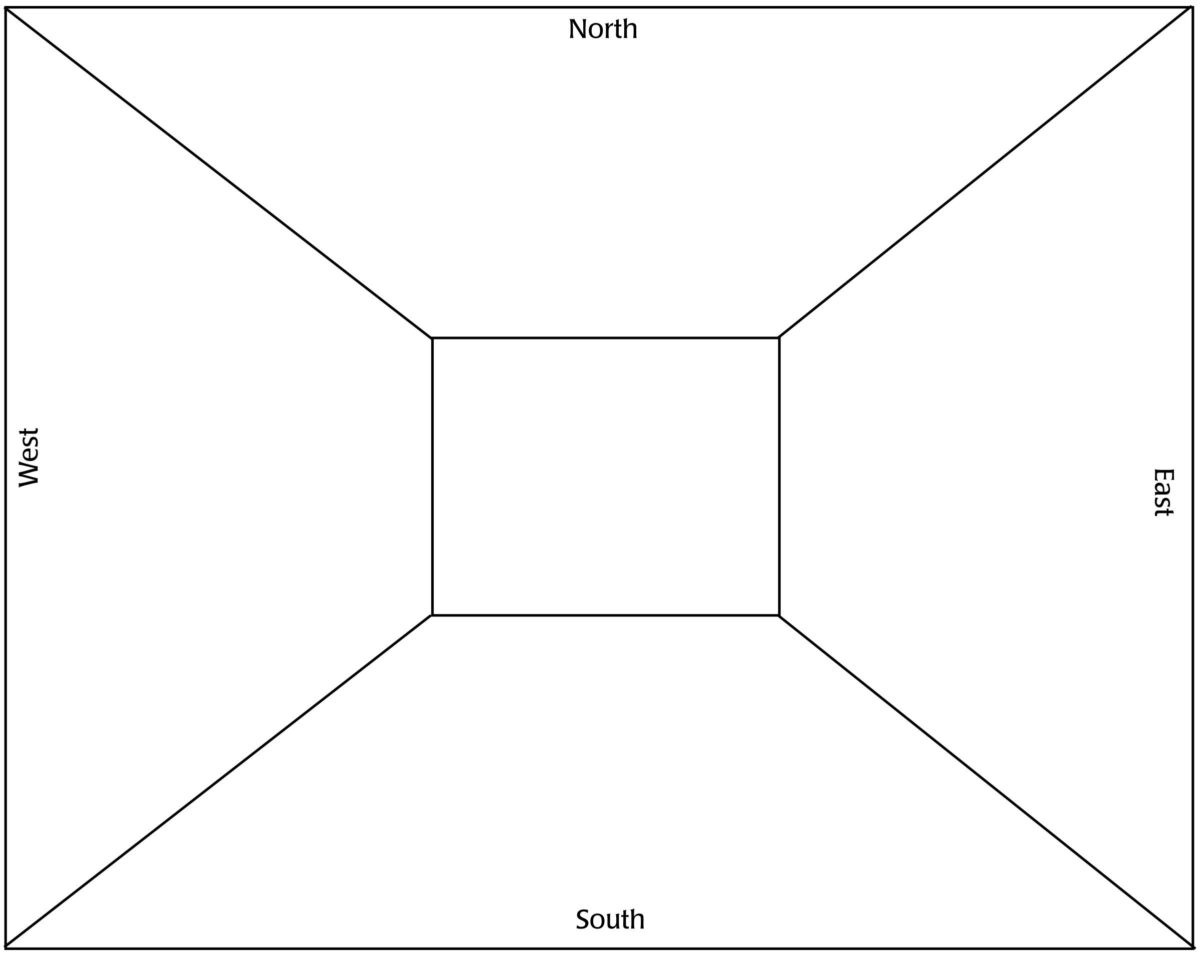
Further Investigations

1. Visit the sites selected in the Intermediate activities again at different seasons and repeat the investigation. How have the various factors changed? What factors influenced the change? What factors might have influenced the leaf on or off process during the course of the year?
2. Have students construct terrariums. Try to make the terrarium more like one of your above system sites. Add wind, moderate the temperature, water, and check for sunlight, add plants, mimic animal effects. Try to model your system based upon the data you received from your investigation. Try for seasonal variations. Can you do it? What limitations are there to the models? Can you develop the same cycles that exist in nature between the living and nonliving factors?

Figure LAND-L-32: Site Seeing - Biology Study Site Sketch Work Sheet

Date:

Name(s):



Site Seeing
Biology Field Site Work Sheet

Date: **Name:**

Study Site Type (circle one): Wetland Field 30 x 30 m Biology Study Site

Temperature (C) at: 0.5 m elevation:

Ground Level:

2.5 cm Depth:

Accumulated precipitation from the growing season (mm):

Sunlight:

Wind (Beaufort Scale):

Animal and Plant Life:

Table LAND-L-16: Beaufor t Scale Work Sheet

Wind Speed kmph	mph	Beaufort Number	Wind Description	Observed Effects on Land
<1	<1	0	Calm	Calm, no movement of leaves
1–3	1–3	1	Light air	Slight leaf movement, smoke drifts, wind vanes moving
6–11	4–7	2	Light breeze	Leaves rustling, wind felt, wind vanes moving
12–19	8–12	3	Gentle breeze	Leaves and twigs in motion, small flags and banners extended
20–29	13–18	4	Moderate breeze	Small branches moving; raising dust, paper litter, and dry leaves
30–38	19–24	5	Fresh breeze	Small trees and branches swaying, wavelets forming on inland water ways
39–49	25–31	6	Strong breeze	Large branches swaying, overhead wires whistling, difficult to control an umbrella
50–61	32–38	7	Moderate gale	Entire trees moving, difficult of walk into wind
62–74	39–46	8	Fresh gale	Small branches breaking, difficult to walk, moving automobiles drifting and veering
75–87	47–54	9	Strong gale	Roof shingles blown away, slight damage to structures, broken branches littering the ground
88–101	55-63	10	Whole gale	Uprooted and broken trees, structural damage
102–116	64–73	11	Storm	Widespread damage to structures and trees, a rare occurrence
>117	>74	12–17	Hurricane	Severe to catastrophic damage

Seasonal Changes in Your Biology Study Site(s)

Purpose

To investigate seasonal changes by collecting data on spring bud-break and fall leaf senescence

Overview

In the Fall and Spring, students conduct measurements of seasonal changes in the green canopy and/or grasslands. In the spring, they measure bud-break, and in the Fall they measure leaf senescence. They do these measurements every week, for six weeks in the Fall and six weeks in the Spring. Students then investigate the rate of change based on the data they collected.

Time

Two class periods to introduce the activity and explore the data

Also, a small group of students needs to collect the data, one period per week, for a six weeks in the Fall and six weeks in the Spring.

Level

Intermediate or Advanced

Key Concepts

In the Spring, there is a period of bud-break, in which leaf buds appear and grow.

In the Fall, there is a period of senescence, in which actively growing plant material dies.

Skills

Measuring tree canopy

Analyzing data for Spring and Fall changes over time

Materials and Tools

Tubular Densiometer

See Land Cover/Biology Protocol *Identification of Dominant and Co-Dominant Species.*

Prerequisites

Students should know how to use the tubular densiometer. See Land Cover/Biology Protocol *Identification of Dominant and Co-Dominant Species.*

Background

This learning activity focuses on the changing lengths of growing seasons for different parts of the Earth. In order to determine the length of growing season for your area, researchers, and you and your students, can monitor the development of a green canopy and/or grasslands from spring “bud-break” to autumnal senescence (the death of actively growing plant material.) Satellite data and images can be used to track the “green wave” in the spring, as it moves from south to north in the northern hemisphere, and the “brown wave” in the fall, as it moves from north to south. In the southern hemisphere the “green wave” moves in the reverse direction, from north to south and the “brown wave” moves from south to north.

One of the disadvantages of using satellite data is that the spatial resolution may be poor. This means that many ground features such as individual trees or stands of trees will not be seen directly. Thus researchers working with satellite imagery need more detailed information about what is happening in the vegetated land cover types that are contributing to the data monitored by the satellites. Two very critical times of the year are the “spring” leaf-out and the “fall” senescence, for they define the length of the growing season for a particular place on the Earth’s surface. Your studies in this activity will add to your understanding of these critical times in your area in a very significant way.

Depending on your location, your climate or vegetation types may not lend themselves to the observation of the seasonal events described here.

What To Do and How To Do It

If your GLOBE Biology Study Site contains deciduous trees:

Bud-break:

1. Using the 30 m x 30 m Biology Study Site, select a day in early spring just as leaves are beginning to emerge to conduct an assessment of percent canopy closure, using the tubular densiometer method. See Land Cover/Biology Protocol *Identification of Dominant and Co-Dominant Species*.
2. Once per week, for the next five weeks, (for a total of six weeks) conduct the same canopy closure assessment, using the same method.
3. Record your data, and save it for study of the year-to-year changes in bud-break.

Senescence:

1. Using the same 30 m X 30 m Biology Study Site, select a day when the first signs of autumnal color change in foliage are seen. Conduct an assessment of percent canopy closure (see Land Cover/ Biology Protocol I*dentification of Dominant and Co-Dominant Species*), with the following change in method.
2. Measure canopy closure, using the tubular densiometer, but instead of recording just (+'s) and (-'s), record "g" if you see green leaves, "b" if you see brown or colored leaves, and (-) if you see no foliage. This is the same method you used for brown and green ground cover.
3. Calculate the percentages of green and brown canopy in the same manner as you calculated ground cover.
4. Once per week, for the next five weeks, repeat this observation.
5. Record your data and save it for year-to-year studies of changes in senescence.

Grassland areas: Just as the timing of bud-break and senescence are important indicators in forests, the timing of changes in grassland vegetation is also an important indicator. In grassland, the timing of the beginning and end of active growth, the occurrence of flowering and fruiting, and senescence are significant, observable changes that describe the growing season, that can be measured by you and your students.

If your GLOBE Biology Study Site contains grasses:

Bud-break:

1. Using the 30 m X 30 m Biology Study Site (in this case, one in which grass is dominant or co-dominant), select a day in early spring just as the grasses are beginning to turn green.
2. Measure the percentages of brown and green ground cover in the same manner described in the ground cover protocol.
3. Once per week, for the next five weeks, repeat this ground cover survey.

Senescence:

1. Repeat the ground cover measurements above when grasses begin to turn brown. The timing of the browning may or may not coincide with the fall period in your area; if, for example, a lack of rain makes the grass turn brown. You will need to observe your grasslands area to decide when to begin this measurement.

Going Farther – An Extension

A significant event in grasslands is the formation of flowering heads and fruiting heads. Since it may be difficult for you and your students to determine the difference between grass flowers and fruits, simply note the time of year when the grass changes from growing leaves (grass blades) to growing a central stalk, which elongates, eventually becoming topped by the flowering/ fruiting head. Note the timing of this event, within one week, and record this it in your data archive.

Changes from year-to-year in the timing and lengths of the events measured in this exercise will give you and your students a way of relating changes in your other GLOBE measurements (temperature, precipitation, etc.) to their effects on your local environment.

To help you and your students evaluate these seasonal changes, see the suggestions in the *Seasons Investigation* later in the GLOBE Teacher's Guide.

Appendix

Figure LAND-A-1: Clinometer Sheet

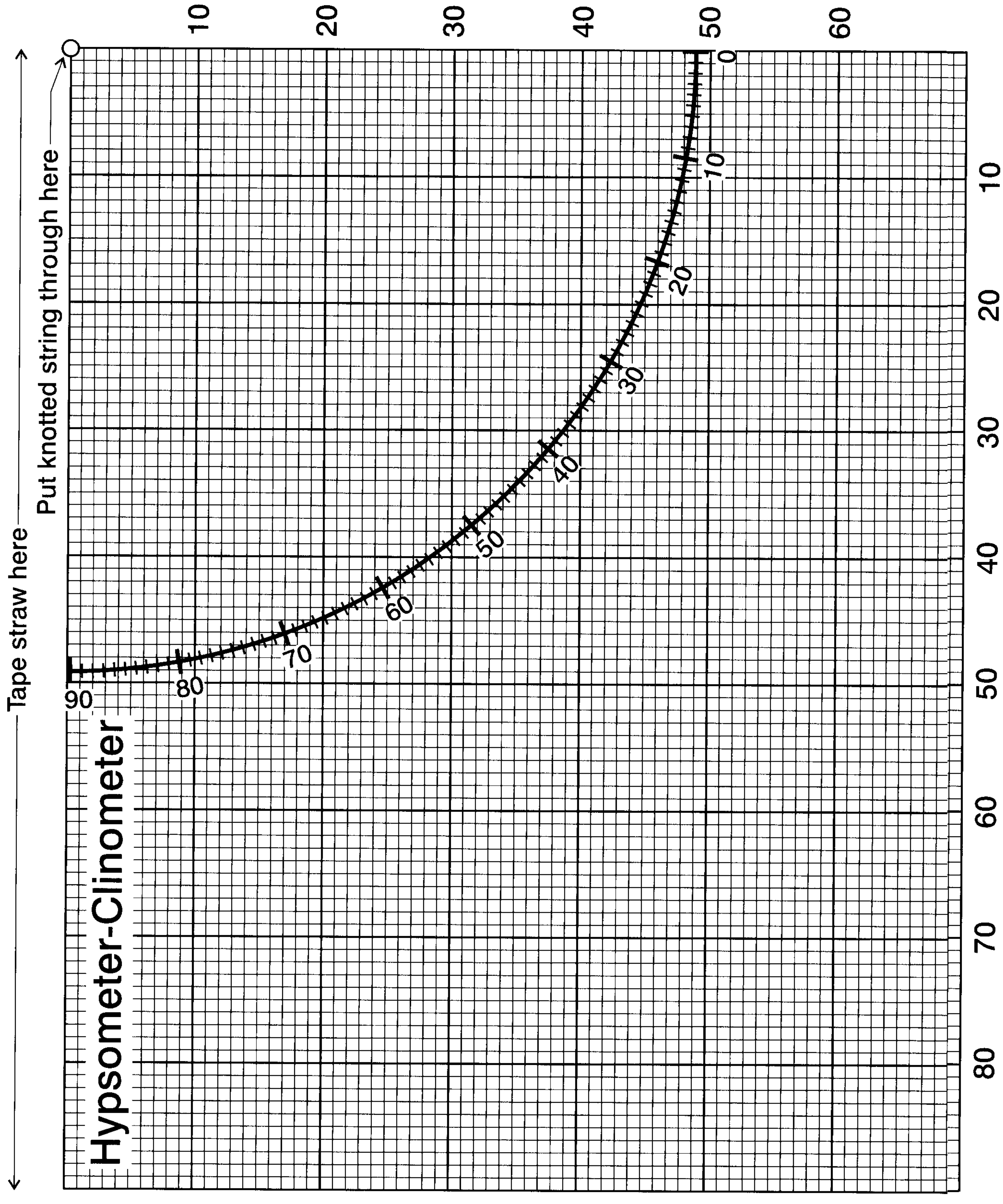


Table LAND-A-1: Table of Tangents

Angle	Tan.	Angle	Tan.	Angle	Tan.	Angle	Tan.	Angle	Tan.
1°	.02	17	.31	33	.65	49	1.15	65	2.14
2	.03	18	.32	34	.67	50	1.19	66	2.25
3	.05	19	.34	35	.70	51	1.23	67	2.36
4	.07	20	.36	36	.73	52	1.28	68	2.48
5	.09	21	.38	37	.75	53	1.33	69	2.61
6	.11	22	.40	38	.78	54	1.38	70	2.75
7	.12	23	.42	39	.81	55	1.43	71	2.90
8	.14	24	.45	40	.84	56	1.48	72	3.08
9	.16	25	.47	41	.87	57	1.54	73	3.27
10	.18	26	.49	42	.90	58	1.60	74	3.49
11	.19	27	.51	43	.93	59	1.66	75	3.73
12	.21	28	.53	44	.97	60	1.73	76	4.01
13	.23	29	.55	45	1.00	61	1.80	77	4.33
14	.25	30	.58	46	1.04	62	1.88	78	4.70
15	.27	31	.60	47	1.07	63	1.96	79	5.14
16	.29	32	.62	48	1.11	64	2.05	80	5.67

Example: Assume you have established a baseline distance of 60 meters. Assume that you have measured the tree top to an angle of 24°. From the Table, you will see that the tangent of 24° is 0.45. Therefore, the tree height is 60m x 0.45 = 27 meters. By adding the height of the eyes of the observer (1.5m), the total tree height is 28.5 meters.

Land Cover/Biology

Dominant/Co-Dominant Vegetation Data Work Sheet

	Use these columns to determine: Overall Canopy & Ground Cover		Use these columns to determine: Dominant & Co-Dominant Canopy Species or Ground Vegetation Type		Use this column to derive MUC for forest or woodland
	Canopy Observations + = Canopy - = Sky	**Ground Observations** G = Green Cover B = Brown Cover - = No Cover	**Canopy Species/Common Name**	**Ground Vegetation Type** graminoid or forb	**Canopy Type** E = Evergreen D = Deciduous S = Sky
1					
2					
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10					
11					
12					
13					
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40					

(See Work Sheet for Calculations)

Canopy Cover	Ground Cover
%	%

Dominant Canopy Species or Ground Vegetation Type:
Co-Dominant Canopy Species or Ground Vegetation Type:

Dominant/Co-Dominant Vegetation Data Work Sheet (continued)

Determining Canopy Cover:

Total +'s = ____________

Total –'s = ____________

Total Observations = ____________

% Canopy Cover
(+'s/Total Observations) = ____________ ← **Report This!**

Determining Ground Cover:

Total G's = ____________

Total B's = ____________

Total –'s = ____________

Total Observations = ____________

% Ground Cover
(G+B/Total Observations) = ____________ ← **Report This!**

If Forest or Woodland Cover Type:

Determining Percentage Evergreen and Deciduous:

Total number of E's = ____________

Total number of D's = ____________

Total Canopy (E + D) = ____________

% Evergreen
(E's/Total Canopy) = ____________

% Deciduous
(D's/Total Canopy) = ____________

Use to determine MUC if forest or woodland
See MUC Protocol

If Herbaceous Cover Type:

Determining Percentage graminoid or forb:

Total number of grasses = ____________

Total number of forbs = ____________

Total Observations = ____________

% Grass
(Grass/Total Observations) = ____________

% Forbs
(Forbs/Total Observations) = ____________

Use to determine MUC if herbaceous
See MUC Protocol

Land Cover/Biology Investigation

Field Data Work Sheet

★For Land Cover Sites Only:

★Type of Site:

❑ Biology Site
❑ Land Cover Site

❑ Training Site
❑ Validation Site

❑ Qualitative Site
❑ Quantitative Site

Site Name:____________________ ★Country/State/City:___________________________

★GPS Location: Lat.______________ Long.______________

★Date:__________ ★Time:___________ Recorded by:___________________________

MUC Level 1 Land Cover Class: Name: ________ Code:________

If class 2, 3, or 5 - 9, **Stop Here.** If this is a Qualitative site, **Stop Here.**

Dominant & Co-Dominant Vegetation (Genus & Species) -- See Dominant/Co-Dominant Vegetation Field Form.

If Forest or Woodland: ★Dominant:_______ _______ ★Co-Dominant:_______ _______

If Herbaceous:

★ Dominant: ❑ Grass ❑ Forb

★ Co-Dominant: ❑ Grass ❑ Forb ❑ Trees: Genus:________ Species:________

Biometry Data

Record Data from the *Dominant/Co-Dominant Vegetation Work Sheet*

Canopy Cover:

Total +′s_____ Total −′s_____ Total Observations_______ % Canopy___________

Ground Cover:
Total G's_____ Total B's_____ Total -'s_____ Total Observations_______ % Ground Cover__ _

Percent Evergreen and Deciduous:
Total E's_____ Total D's_____ Total Canopy (E + D)_____ % Evergreen_____ % Decid.____

Percent Graminoid or Forb:
Total Grasses_____ Total Forbs_____ Total Obs._____ % Grass_____ % Forbs_____

Dominant Species:________ ________	**Co-Dominant Species:**________ ________
Tree Height:___m ___m ___m ___m ___m	Tree Height:___m ___m ___m ___m ___m
Tree DBH:___cm___cm___cm___cm___cm	Tree DBH:___cm___cm___cm___cm___cm
If Grass- Green Biomass:___g/m^2 ___g/m^2 ___g/m^2	If Grass- Green Biomass:___g/m^2 ___g/m^2 ___g/m^2
Brown Biomass:___g/m^2 ___g/m^2 ___g/m^2	Brown Biomass:___g/m^2 ___g/m^2 ___g/m^2

Biometry Summary

★Canopy Cover:_____%

★Ground Cover: Green:_____% Brown:_____% Total: ______%

★Average Tree Height:____m ★Average Tree DBH:____cm

★Avg. Green Biomass:____g/m^2 ★Avg. Brown Biomass:____g/m^2 ★Total Biomass:____g/m^2

MUC Land Cover Class

★**Level 2** Name:_________ Code:_________

★**Level 3** Name:_________ Code:_________

★**Level 4** Name:_________ Code:_________

Notes:____

____

Photographs:____

____

Phenology (optional)

★Event (check one): ❑ Bud-Break ❑ Senescence

(Do canopy cover or ground cover measurements - other side)

★Canopy Cover:____% ★Percent Green in Canopy (estimate):____%

★Ground Cover: Green____% Brown____% Total:____%

Land Cover/Biology Investigation

MUC Classification Data Work Sheet

Sample Number	Site Name	Student Classification from MultiSpec or Manual Interpretation	Validation Data from ground visitation	Correct	Incorrect

Glossary of Terms in the Modified UNESCO Classification Scheme (MUC)

This glossary provides definitions, decision criteria, and examples of all the land cover types outlined in the Modified UNESCO Classification Scheme (MUC). It should be used as the primary reference to determine what land cover classes to report in the Land Cover Module Protocols.

The glossary contains four columns of information:

1. The MUC classification code (used to report land cover types in the Land Cover and Accuracy Assessment Protocols)
2. The name of the land cover class
3. The MUC class level
4. The definitions, decision criteria, and examples

MUC Code	Name of Land Cover Class	MUC level	Definitions, Decision Criteria, and Examples
0	Closed Forest	level 1	Formed by trees at least 5 meters tall with their crowns interlocking. Total canopy cover is greater than 40%.
01	Mainly Evergreen Forest	level 2	The canopy is never without green foliage . . .
011	Tropical Wet Forest	level 3	Often called a tropical rain forest. Consisting mainly of broad-leaved evergreen trees . . .
0111	Lowland Forest	level 4	Consists of fast growing trees, many exceeding 50 meters tall and usually forming an uneven canopy . . .

The land cover types are organized numerically in the same order as the classes appear in the MUC Classification Scheme. Miscellaneous terms used in the glossary are defined following the numbered MUC definitions.

Be sure to note the difference between determining the percentage ground coverage (the entire area which is under the canopy or foliage of the vegetation) and the percentage species composition. The overall canopy or ground coverage determines the dominant level 1 land cover type for the specific area on the satellite image. The percent species composition of the dominant cover type (from level 1) determines which level 2 land cover classification is appropriate. Levels 3 and 4 are more specific descriptions of plant communities and may be determined by either ground coverage or percent species composition as defined in the glossary.

For an example, see the following heading in the *miscellaneous terms* section of the glossary: **Classification using MUC, % Cover vs. % Species Composition**

References: *A land use and land cover classification system for use with remote sensor data.* J.R. Anderson, E.E. Hardy, J.T. Roach, and R.E. Witmer. U.S. Geol. Survey. Prof. Pap., 1976.

Classification of Wetlands and Deepwater Habitats of the United States. L.M. Cowardin, V. Carter, F.C. Golet, and E.T. LaRoe. U.S. Fish and Wildlife. Services. FWS/OBS-79/31, 1979.

International Classification and Mapping of Vegetation. United Nations Educational, Scientific and Cultural Organization. Switzerland: UNESCO, 1973.

NOAA Coastal Change Analysis Program (C-CAP): Guidance for Regional Implementation. J.E. Dobson et al. NOAA Technical Report NMFS 123, 1995.

MUC Code	Glossary of Terms in the Modified Classification Scheme	Class Level	
0	Closed Forest	level 1	Formed by trees at least 5 meters tall with their crowns interlocking. Total canopy cover is greater than 40%.
01	Mainly Evergreen Forest	level 2	The canopy is never without green foliage. At least 50% of the trees that reach the canopy are evergreen. Individual trees may shed their leaves.
011	Tropical Wet Forest	level 3	Often called a tropical rain forest. Consisting mainly of broad-leaved evergreen trees, neither cold nor drought resistant. Truly evergreen, i.e. the forest canopy remains green all year though a few individual trees may be leafless for a few weeks. Leaves of many species have "drip tip".
0111	Lowland forest	level 4	Consists of fast growing trees, many exceeding 50 meters tall and usually forming an uneven canopy. Undergrowth is sparse, lichen and green algae are present, and climbing vines are absent.
0112	Submontane forest	level 4	Trees form an even canopy. Forbs are common in the undergrowth. Vascular epiphytes and vines are abundant, e.g., Atlantic slopes of Costa Rica.
0113	Montane forest	level 4	Trees are less than 50 meters tall, have crowns that extend relatively far down the stem and have rough bark. Usually ferns, herbs, mosses, and small palms are abundant in the undergrowth, e.g., Sierra de Talamanca, Costa Rica.
0114	"Subalpine" forest	level 4	Occurs at elevations above montane forests, with characteristic vegetation which is dependent on latitude.
0115	Cloud forest	level 4	Trees are gnarled , have rough bark and are rarely greater than 20 meters tall. Tree crowns, branches and trunks are burdened with epiphytes and vines, e.g., Blue Mountains, Jamacia.
012	Tropical and Subtropical Evergreen Seasonal	level 3	Consisting mainly of broad-leaved evergreen trees. Foliage reduction during the dry season is noticeable, often as partial shedding. Transitional between Tropical Wet Forest and Tropical and Subtropical Semi-deciduous.
0121	Lowland forest	level 4	Consists of fast growing trees, many exceeding 50 meters tall and usually forming an uneven canopy. Undergrowth is sparse, lichen and green algae are present, and climbing vines are absent.

MUC Code	Glossary of Terms in the Modified Classification Scheme	Class Level	
0122	Submontane forest	level 4	Trees form an even canopy. Forbs are common in the undergrowth. Vascular epiphytes and vines are abundant.
0123	Montane forest	level 4	Trees are less than 50 meters tall, have crowns that extend relatively far down the stem and have rough bark. Evergreen shrubs are more common than tree ferns in the undergrowth.
0124	" Subalpine" forest	level 4	This forest resembles the Winter-rain Evergreen Broad-leaved Sclerophyllous dry forest and usually occurs above the cloud forest. Trees are mostly evergreen sclerophyllous trees, smaller than 20 meters with little or no undergrowth, few climbing vines, and few epiphytes.
013	Tropical and Subtropical Semi-deciduous (upper canopy drought deciduous)	level 3	Most of the upper canopy trees are drought-deciduous; many of the understory trees and shrubs are evergreen and more or less sclerophyllous. However, evergreen and deciduous woody plants and shrubs may occur mixed within the same layer. Nearly all trees have bud protection and leaves without " drip tips" . Trees have rough bark, except some bottle trees, which may be present.
0131	Lowland forest	level 4	The taller trees may be bottle trees (e.g.,Ceiba). There are practically no epiphytes present. The undergrowth is composed of shrubs and seedlings. Succulents such as thin-stemmed caespitose cacti are also present. Vines and sparse layer of herbaceous vegetation may also be present.
0133	Montane or cloud forest	level 4	This forest is similar to a Semi-deciduous Lowland Forest, however, the canopy is lower and covered with xerophytic epiphytes such as *Tillandsia usneoides.*
014	Subtropical Wet Forest	level 3	Present only locally and in small fragmentary stands, because the subtropical climate typically has a dry season. Subtropical Wet Forest (e.g., in Queensland, Australia and Taiwan) usually grades into tropical wet forest. Some shrubs may grow in the understory. Seasonal temperature change occurs between summer and winter.
0141	Lowland forest	level 4	Consists of fast growing trees, many exceeding 50 meters tall and usually forming an uneven canopy. Undergrowth is sparse, lichen and green algae are present, and climbing vines are absent.
0142	Submontane forest	level 4	Trees form an even canopy. Forbs are common in the undergrowth. Vascular epiphytes and vines are abundant.

MUC Code	Glossary of Terms in the Modified Classification Scheme	Class Level	
0143	Montane forest	level 4	Trees are less than 50 meters tall, have crowns that extend relatively far down the stem and have rough bark. Usually ferns, herbs, mosses, and small palms are abundant in the undergrowth.
0144	ÒSubalpineÓforest	level 4	Occurs at elevations above montane forests, with characteristic vegetation which is dependent on latitude.
0145	Cloud forest	level 4	Trees are gnarled, have rough bark and are rarely greater than 20 meters tall. Tree crowns, branches and trunks are burdened with epiphytes and vines.
015	Temperate and Subpolar Evergreen Wet Forest	level 3	Occurs only in the extremely oceanic, nearly frost-free climates of the southern hemisphere, mainly in Chile. Consisting mostly of truly evergreen hemisclerophyllous trees and shrubs. Rich in epiphytic mosses, liverworts, lichens that grow on trees, and in ground-rooted herbaceous ferns.
0151	Temperate evergreen wet forest	level 4	Trees are greater than 10 meters tall. Vascular epiphytes and vines may be present.
0152	Subpolar evergreen wet forest	level 4	Trees are less than 10 meters tall and often have reduced leaf size. There are no vascular epiphytes present.
016	Temperate Evergreen Deciduous Broad-leaved Forest	level 3	Requires adequate summer rainfall. This is a mixed evergreen-deciduous class. The dominant trees are mainly hemi-schlerophyllous evergreen trees (more than 50% of the canopy) and shrubs, and the subdominant trees are deciduous broad-leaved trees and shrubs (more than 25% of the canopy). Rich in perennial herbaceous plants. Very few or no vascular epiphytes and vines.
0161	Lowland forest	level 4	Consists of fast growing trees, many exceeding 50 meters tall and usually forming an uneven canopy. Undergrowth is sparse, lichen and green algae are present, and climbing vines are absent.
0162	Submontane forest	level 4	Trees form an even canopy. Forbs are common in the undergrowth. Vascular epiphytes and vines are abundant.
0163	Montane forest	level 4	Trees are less than 50 meters tall, have crowns that extend relatively far down the stem and have rough bark. Usually ferns, herbs, mosses, and small palms are abundant in the undergrowth.
0164	“ Subalpine” forest	level 4	Occurs at elevations above montane forests, with characteristic vegetation which is dependent on latitude.

MUC Code	Glossary of Terms in the Modified Classification Scheme	Class Level	
017	Winter-Rain Evergreen Broad-leaved Sclerophyllous	level 3	Often understood as Mediterranean, but present also in south-western Australia, Chile, and other locations. The climate has a pronounced summer drought. The trees are mainly of sclerophyllous evergreen trees and shrubs, most of which have rough bark. There is very little herbaceous undergrowth. No vascular and few epiphytic bryophytes (mosses and liverworts) and lichens, but evergreen woody vines are present.
0171	Lowland and submontane > 50 m	level 4	Dominated by trees over 50 meters tall (more than 50% of the canopy) such as giant eucalypts, e.g., *Eucalyptus regnans* in Victoria and E. *diversicolor* in Western Australia.
0172	Lowland and submontane < 50 m	level 4	Dominated by trees less than 50 meters tall (more than 50% of the canopy), e.g., Californian live-oak forest.
018	Tropical and Subtropical Evergreen Needle-leaved	level 3	Consisting mainly of needle-leaved or scale-leaved evergreen trees (more than 50% of the canopy). Broad-leaved trees may be present. Vascular epiphytes and vines rarely present.
0181	Lowland and submontane	level 4	E.g., the pine forests of Honduras and Nicaragua.
0182	Montane and subalpine	level 4	E.g., the pine forest of the Philippines and southern Mexico.
019	Temperate and Subpolar Evergreen Needle-leaved	level 3	Consisting mainly of needle-leaved or scale-leaved evergreen trees (more than 50% of the canopy), but broad-leaved trees may be present. Vascular epiphytes and vines are rarely present.
0191	Giant forest	level 4	Dominated by trees (more than 50% of the canopy) greater than 50 meters tall, e.g., *Sequoia* and *Pseudo-tsuga* forest in the Pacific West of North America.
0192	Rounded crowns	level 4	Dominated by trees 45-50 meters tall (more than 50% of the canopy), with broad, irregularly rounded crowns, e.g., *Pinus* spp.
0193	Conical crowns	level 4	Dominated by trees 45-50 meters tall (more than 50% of the canopy), with conical crowns, e.g., *Picea*, *Abies*, California red fir forests.
0194	Cylindrical crowns	level 4	Dominated by trees 45-50 meters tall (more than 50% of the canopy), with crowns with very short branches and a narrow cylindrical shape.

MUC Code	Glossary of Terms in the Modified Classification Scheme	Class Level	
02	Mainly Deciduous Forest	level 2	The majority of trees (more than 50% of the canopy) shed their foliage simultaneously in connection with the unfavorable season (drought or cold).
021	Tropical and Subtropical Drought-deciduous	level 3	The unfavorable season is mainly characterized by drought, in most cases winter-drought. Foliage is shed regularly every year. Most trees have relatively thick, fissured bark.
0211	Broad-leaved lowland and submontane	level 4	Practically no evergreen plants in any stratum, except some succulents. Woody and herbaceous vines and deciduous bottle-trees are present. Sparse herbaceous vegetation present in the undergrowth, e.g., the broad-leaved deciduous forest of north-western Costa Rica.
0212	Montane and cloud forest	level 4	Some evergreen species are present in the understory. Drought resistant epiphytes are present or abundant, often in the bearded form (e.g., *Usnea* or *Tillandsia usneoides*). This formation is not frequent, but well developed, e.g., in northern Peru.
022	Cold-deciduous Forest with Evergreen Trees and Shrubs	level 3	The unfavorable season is mainly characterized by winter frost. Deciduous broad-leaved trees are dominant (more than 50% of the canopy), but evergreen species are present (more than 25% of the canopy) as part of the main canopy or the understory. Climbers and vascular epiphytes are scarce or absent.
0221	With evergreen broad-leaved trees and climbers	level 4	Rich in epiphytes and mosses. Vascular epiphytes may be present at the base of tree stems. Climbing vines may be common on flood plains. *Ilex aquifolium* and *Hedera helix* in western Europe and *Magnolia* spp. in North America are examples of this class type.
0222	With evergreen needle-leaved trees	level 4	E.g., the maple-hemlock or oak-pine forests of Northeastern, U.S.A.
023	Cold-deciduous Forests without Evergreen Trees	level 3	Deciduous trees are absolutely dominant (more than 75% of the canopy). Evergreen herbs and some evergreen shrubs (less than 2 meters tall) may be present. Climbers insignificant but may be common on flood plains; vascular epiphytes are absent (except occasionally at the lower base of the tree); mosses, liverworts and particularly lichens are always present.
0231	Temperate lowland and submontane broad-leaved	level 4	Trees are up to 50 meters tall. Epiphytes are primarily algae and crustose lichens.

MUC Code	Glossary of Terms in the Modified Classification Scheme	Class Level	
0232	Montane or boreal	level 4	Trees may be up to 50 meters tall, but in montane or boreal forest normally not taller than 30 meters. Epiphytes are primarily lichens and bryophytes. This class includes lowland or submontane in topographic positions with high atmospheric humidity.
0233	Subalpine or subpolar	level 4	Trees are not taller than 20 meters and have gnarled trunks. Epiphytes are lichens and bryophytes and are more abundant than in the montane class (0232). This class often grades into woodland.
03	Extremely Xeromorphic (dry) Forest	level 2	Dense stands of trees and shrubs adapted to dry conditions, such as bottle trees, tuft trees with succulent leaves and stem succulents. Undergrowth has shrubs adapted to dry conditions, succulent perennial herbs and annual and perennial herbaceous plants. Often grades into woodlands.
031	Sclerophyllous-dominated Extremely Xeromorphic	level 3	Vegetation similar to Xeromorphic Forest, with predominance of sclerophyllous trees, many of which have bulbose stem bases largely embedded in the soil.
032	Thorn Forest	level 3	Species with thorns are dominant (more than 50% of the canopy).
0321	Mixed deciduous-evergreen thorn forest	level 4	Both deciduous species and evergreen species are more than 25% of the tree canopy. See definitions of Mainly Evergreen Forest, class 01 and Deciduous, class 02.
0322	Purely deciduous thorn forest	level 4	Deciduous thorn species are absolutely dominant (more than 75% of the canopy). See definition of Deciduous Forest, class 02.
033	Mainly Succulent Forest	level 3	Tree-formed (scapose) and shrub-formed (caespitose) succulents are very frequent (more than 50% of the canopy), but other trees and shrubs adapted to dry conditions are usually present as well.

MUC Code	Glossary of Terms in the Modified Classification Scheme	Class Level	
1	Woodland	level 1	Comprised of open stands of trees more than 5 meters tall with crowns not touching. Greater than 40% of the ground is covered by the tree canopy. Definitions for Mainly Evergreen Woodland, Mainly Deciduous Woodland, and Extremely Xeromorphic Woodland are similar to forest definitions with sparser stocking of individual trees.
11	Mainly Evergreen Woodland	level 2	The canopy is never withoug green foliage. At least 50% of the trees that reach the canopy are evergreen. Individual trees may shed their leaves.
111	Evergreen Broad-leaved Woodland	level 3	Mainly sclerophyllous trees and shrubs, with no epiphytes.
112	Evergreen Needle-leaved Woodland	level 3	Trees are mainly needle- or scale-leaved (more than 50% of the canopy). Crowns of many trees extend to the base of the stem or are very branchy.
1121	Rounded crowns	level 4	E.g., *Pinus.*
1122	Conical crowns prevailing	level 4	Usually in subalpine areas.
1123	Narrow cylindrical crowns	level 4	E.g., *Picea* in the boreal regions.
12	Mainly Deciduous Woodland	level 2	The majority of trees (more than 50% of the canopy) shed their foliage simultaneously in connection with the unfavorable season (drought or cold).
121	Drought-deciduous	level 3	The unfavorable season is mainly characterized by drought, in most cases winter-drought. Foliage is shed regularly every year. Most trees have relatively thick, fissured bark.
1211	Broad-leaved lowland and submontane	level 4	Practically no evergreen plants in any stratum, except some succulents. Woody and herbaceous vines and deciduous bottle-trees are present. Sparse herbaceous vegetation present in the undergrowth.
1212	Montane and cloud woodland	level 4	Some evergreen species are present in the understory. Drought resistant epiphytes are present or abundant, often in the bearded form (e.g., *Usnea* or *Tillandsia usneoides*). This formation is not frequent, but well developed, e.g., in northern Peru.

MUC Code	Glossary of Terms in the Modified Classification Scheme	Class Level	
122	Cold-deciduous with Evergreens	level 3	The unfavorable season is mainly characterized by winter frost. Deciduous broad-leaved trees are dominant (more than 50% of the canopy), but evergreen species are present (more than 25% of the canopy) as part of the main canopy or the understory. Climbers and vascular epiphytes are scarce or absent.
1221	With evergreen broad-leaved trees and climbers	level 4	Rich in epiphytes and mosses. Vascular epiphytes may be present at the base of tree stems. Climbing vines may be common on flood plains. *Ilex aquifolium* and *Hedera helix* in western Europe and Magnolia spp. in North America are examples of this class type.
1222	With evergreen needle-leaved trees	level 4	E.g., the maple-hemlock or oak-pine forests of Northeastern, U.S.A.
123	Cold-deciduous without Evergreens	level 3	Deciduous trees are absolutely dominant (more than 75% of the canopy). Evergreen herbs and some evergreen shrubs (less than 2 meters tall) may be present. Climbers insignificant but may be common on flood plains; vascular epiphytes are absent (except occasionally at the lower base of the tree); mosses, liverworts and particularly lichens are always present. Cold-deciduous species are absolutely dominant (more than 75% of the canopy). Most frequent in the subarctic region, elsewhere only on swamps or bogs.
1231	Broad-leaved deciduous	level 4	Broad-leaved deciduous species are absolutely dominant (more than 75% of the canopy).
1232	Needle-leaved deciduous	level 4	Needle-leaved deciduous species are absolutely dominant (more than 75% of the canopy).
1233	Mixed deciduous	level 4	Both broad-leaved and needle leaved deciduous species provide more than 25% of the canopy.
13	Extremely Xeromorphic Woodland	level 2	Stands of trees and shrubs adapted to dry conditions, such as bottle trees, tuft trees with succulent leaves and stem succulents. Undergrowth has shrubs adapted to dry conditions, succulent perennial herbs and annual and pernnial herbaceous plants. Woodlands may grade into forest.
131	Sclerophyllous-dominated Extremely Xeromorphic	level 3	Vegetation is similar to Xeromorphic woodlands, with predominance of sclerophyllous trees, many of which have bulbose stem bases largely embedded in the soil.

MUC Code	Glossary of Terms in the Modified Classification Scheme	Class Level	
132	Thorn Woodland	level 3	Species with thorms are dominant (more than 50% of the canopy).
1321	Mixed deciduous-evergreen	level 4	Both deciduous species and evergreen species are more than 25% of the shrub canopy. See definitions of Mainly Evergreen Forest, class 01 and Deciduous, class 02.
1322	Purely deciduous	level 4	Deciduous thorn species are absolutely dominant (more than 75% of the canopy). See definition of Deciduous Forest, class 02.
133	Mainly Succulent Woodland	level 3	Tree-formed (scapose) and shrub-formed (caespitose) succulents are very f requent (more than 50% of the canopy), but other trees and shrubs adapted to dry conditions are usually present as well.

MUC Code	Glossary of Terms in the Modified Classification Scheme	Class Level	
2	Shrublands or Thickets	level 1	The shrub canopy covers at least 40% of the ground and is composed of matted, clumped or clustered woody plants 0.5 to 5 meters tall. Shrubland: most of the individual shrubs are not touching each other; often with grass growing between shrubs. Thicket: individual shrubs are interlocked. Shrublands are also further defined (like Forests and Woodlands) as Evergreen Broad-leaved, Evergreen Needle-leaved, Mainly Deciduous, etc. Shrubland: most of the individual shrubs are not touching each other; often with grass growing between shrubs.
21	Mainly Evergreen Shrubland	level 2	The canopy is never without green foliage. At least 50% of the shrubs that reach the canopy are evergreen. Individual shrubs may shed their leaves.
211	Evergreen Broad-leaved	level 3	Evergreen broad-leaved species are dominant (more than 50% of the canopy).
2111	Low bamboo thicket	level 4	Occasionally bamboo forms a shrubland. See class 2 for shrubland and thicket definitions.
2112	Evergreen tuft-tree	level 4	Composed of small trees and woody shrubs, e.g., Mediterranean dwarf palm shrubland or Hawaiian tree fern thicket or shrubland.
2113	Broad-leaved hemi-sclerophyllous	level 4	Matted or clumped shrubs and plants with large soft leaves, e.g., subalpine *Rhododendron* thickets, or *Hibiscus tiliaceus* matted thicket of Hawaii.
2114	Broad-leaved sclerophyllous	level 4	E.g., chapparal or macchia.
2115	Suffruticose thicket	level 4	E.g., *Cistus* heath.
212	Evergreen Needle-leaved and Microphyllous	level 3	Dominant species (more than 50% of the canopy) have either needle leaves or small leaves.
2121	Evergreen needle-leaved	level 4	Composed of creeping or lodged needle-leaved shrubs, e.g., *Pinus mughus*, " Krummholz" .
2122	Evergreen microphyllous	level 4	Evergreen species have small leaves, e.g., desert plants, or leaves with a single unbranched vein.
22	Mainly Deciduous	level 2	The majority of shrubs (more than 50% of the canopy) shed their folidage simultaneously in connection with the unfavorable season (cold or drought).

MUC Code	Glossary of Terms in the Modified Classification Scheme	Class Level	
221	Drought-deciduous Mixed with Evergreen Woody Plants	level 3	Drought-deciduous shrubs are dominant (greater than 50% of the canopy) and are mixed with greater than 25% evergreen woody plants.
222	Drought-deciduous without Evergreens	level 3	Drought-deciduous shrubs are absolutely dominant (more than 75% of the canopy).
223	Cold-deciduous	level 3	The unfavorable season is mainly lcharacterized by winter frost. Deciduous shrubs are dominant (more than 50% of the canopy).
2231	Temperate deciduous	level 4	Composed of dense scrub without, or with very little, herbaceous undergrowth.
2232	Subalpine or subpolar	level 4	Composed of upright or lodged matted shrubs with great vegetative regeneration capacity and usually covered by snow for at least half a year.
23	Extremely Xeromorphic (subdesert) Shrubland	level 2	Very open stands of shrubs with various adaptations to dry conditions, such as: extremely thickened, hardened foliage; very reduced leaves; green branches without leaves; or succulent stems, some of them with thorns.
231	Mainly Evergreen	level 3	The canopy is never without green foliage. At least 50% of the shrubs that reach the canopy are evergreen. In extremely dry years some leaves and shoot portions may be shed.
2311	Evergreen subdesert	level 4	Composed of broad-leaved mostly sclerophyllous shrubs, e.g., mulga scrub in Australia, leafless green-stemmed plants, e.g., *Retama retam*, or succulents.
2312	Semi-deciduous	level 4	May consist of either facultatively deciduous shrubs or a combination of evergreen and deciduous shrubs (e.g., evergreen shrubs are dominant, deciduous shrubs cover more than 25%).
232	Deciduous Subdesert Shrubland	level 3	See class 02, Mainly Deciduous Forest.
2321	Without succulents	level 4	Succulents cover less than 25% of the ground.
2322	With succulents	level 4	Succulents cover more than 25% of the ground.

MUC Code	Glossary of Terms in the Modified Classification Scheme	Class Level	
3	Dwarf-shrublands	level 1	Shrubs rarely exceed 50 cm in height (sometimes called heaths or heathlike formations). The shrub canopy covers more than 40% of the ground. Dwarf-shrub classes are distinguished by the cover density. Dwarf-shrub thicket: branches are interlocked; Dwarf-shrubland: individual dwarf-shrubs are isolated or in clumps; Dwarf-shrublands with surface densely covered with mosses or lichens; dwarf-shrubs occurring in small clumps or individually.
31	Mainly Evergreen	level 2	The canopy is never without green foliage. At least 50% of the shrubs that reach the canopy are evergreen. Individual shrubs may shed their leaves.
311	Evergreen Dwarf-shrub Thicket	level 3	Composed of densely closed dwarf-shrub cover which dominates the landscape.
3111	Caespitose thicket	level 4	Shrub branches stand upright and often hold lichens. Cushion-shaped mosses, lichens and other herbaceous plants are often found on the ground, e.g.,*s* heath.
3112	Creeping or matted thicket	level 4	Shrub branches creep along the ground, e.g., *Loiseleuria* heath.
312	Evergreen Dwarf-shrubland	level 3	Open or more loose cover of dwarf-shrubs. Shrub canopies are not interlocked. Herbaceous vegetation covers less than 25% of the ground.
3121	Evergreen cushion	level 4	Shrubs are isolated in clumps forming dense cushions and are often thorny, e.g., Astragalus- and Acantholimon " porcupine" -heath of the East Mediterranean mountains.
313	Mixed Evergreen and Herbaceous Formation	level 3	Shrub canopies are not interlocked. Evergreen shrubs are mixed with herbaceous vegetation (more than 25% of the ground).
3131	True evergreen and herbaceous mixed	level 4	E.g., *Nardus Calluna*-heath.
3132	Partial evergreen and herbaceous mixed	level 4	Many individuals shed parts of their shoot systems during the dry season, e.g., *Phyrgan*a in Greece.
32	Mainly Deciduous	level 2	The majority of shrubs (more than 50% of the canopy) shed their folidage simultaneously in connection with the unfavorable season (cold or drought).
321	Facultative Drought Deciduous	level 3	Dwarf-shrubs shed their foliage only in extremely dry years.

MUC Code	Glossary of Terms in the Modified Classification Scheme	Class Level	
322	Obligate Drought Deciduous	level 3	Densely closed dwarf-shrubs lose all or at least part of their leaves in the dry season.
3221	Drought deciduous caespitose	level 4	Shrub branches stand upright and often hold lichens. Cushion-shaped mosses, lichens and other herbaceous plants are often found on the ground, e.g.,*Calluna* heath.
3222	Drought-deciduous creeping or matted	level 4	Shrub branches creep along the ground, e.g., *Loiseleuria* heath.
3223	Drought-deciduous cushion	level 4	Shrubs are isolated in clumps forming dense cushions and are often thorny, e.g., *Astragalus*- and *Acantholimon* " porcupine" -heath of the East Mediterranean mountains.
3224	Drought-deciduous mixed	level 4	Deciduous and evergreen dwarf-shrubs, caespitose herbaceous plants, succulent perennial herbs, and other life forms intermixed.
323	Cold-deciduous	level 3	Densely closed dwarf-shrubs shed foliage at the beginning of a cold season. Richer in mosses and ferns than the drought-deciduous dwarf-shrub class (322).
3231	Drought-deciduous caespitose	level 4	Deciduous and evergreen dwarf-shrubs, caespitose herbaceous plants, succulent perennial herbs, and other life forms intermixed.
3232	Drought-deciduous creeping or matted	level 4	Shrub branches creep along the ground.
3233	Drought-deciduous cushion	level 4	Shrubs are isolated in clumps forming dense cushions and are often thorny.
3234	Drought-deciduous mixed	level 4	Deciduous and evergreen dwarf-shrubs, caespitose herbaceous plants, succulent perennial herbs, and other life forms intermixed.
33	Extremely Xeromorphic Dwarf-shrubland	level 3	Composed of open formations of dwarf-shrubs, succulents, and herbaceous plants adapted to survive or to avoid a long dry season. Mostly subdesertic. See class 23.
331	Mainly Evergreen	level 3	The canopy is never without green foliage. At least 50% of the shrubs that reach the canopy are evergreen. In extremely dry years some leaves and shoot portions may be shed.

MUC Code	Glossary of Terms in the Modified Classification Scheme	Class Level	
3311	Evergreen subdesert	level 4	Composed of broad-leaved mostly sclerophyllous shrubs, leafless green-stemmed plants, or succulents.
3312	Semi-deciduous	level 4	May consist of either facultatively deciduous shrubs or a combination of evergreen and deciduous shrubs (e.g., evergreen shrubs are dominant, deciduous shubs cover more than 25%).
332	Deciduous Subdesert	level 3	The majority of shrubs (more than 50% of the canopy) shed their folidage simultaneously in connection with the unfavorable season (cold or drought).
3321	Without succulents	level 4	Succulents cover less than 25% of the ground.
3322	With succulents	level 4	Succulents cover more than 25 of the ground.
34	Tundra	level 2	Slowly growing, low formations, consisting mainly of dwarf-shrubs, graminoids, mosses, liverworts and lichens, found beyond the subpolar tree line. Often showing plant patterns caused by freezing movements of the soil. Except in boreal regions, dwarf-shrub formations above the mountain tree line should not be called tundra, because they are as a rule richer in dwarf- shrubs and grasses, and grow taller due to the greater radiation in lower latitudes.
	Tundra, Mainly Bryophyte	level 3	Dominated by mats or small cushions of mosses (more than 50% of the vegetative cover). Groups of dwarf-shrubs are as a rule scattered irregularly and are not very dense. The general aspect is more or less dark green, olive green or brownish.
3411	Caespitose dwarf-shrub/moss tundra	level 4	Clumped or clustered dwarf shrubs are present.
3412	Creeping or matted dwarf-shrub/moss tundra	level 4	Creeping or matted dwarf-shrubs are present.
342	Tundra, Mainly Lichen	level 3	Mats of lichens dominating (more than 50% of the vegetative cover), giving the formation a more or less pronounced gray aspect. Mostly evergreen, creeping or cushion-shaped dwarf-shrubs are present.

MUC Code	Glossary of Terms in the Modified Classification Scheme	Class Level	
4	Herbaceous Vegetation	level 1	Dominated by herbaceous grasses and grass-like plants such as sedges (Carex), rushes (*Juncus*), cattails (*Typha*) and broad-leaved plants such as clover, sunflowers (Helianthus), ferns and milkweeds (*Asclepias*). Total ground coverage must be greater than 60% herbaceous vegetation.
41	Tall Graminoid Vegetation (Tall Grasslands)	level 2	Plant community consists of dominant grasses over 2 meters tall when flowering or mature (more than 50% of the herbaceous vegetation). Forbs may be present but comprise less than 50% of herbaceous vegetation.
411	With Trees Covering 10-40%	level 3	May be with or without shrubs. This is somewhat like a very open woodland with a more or less continuous ground cover (over 60%) of tall graminoids.
4111	Trees: broad-leaved evergreen	level 4	Broad-leaved evergreen species are greater than 50% of the tree canopy.
4112	Trees: broad-leaved semi-evergreen	level 4	Trees present are at least 25% each of broad-leaved evergreen and broad-leaved deciduous trees.
4113	Trees: broad-leaved deciduous	level 4	Similar to class 4112, but seasonally flooded, e.g., in northeast Bolivia.
412	Tall Grass Lands with Trees Covering Less than 10%	level 3	Grassland with trees covering less than 10% of the ground, with or without shrubs.
4120	Trees: needle-leaved evergreen	level 4	Needle-leaved evergreen species are greater than 50% of the tree canopy.
4121	Trees: broad-leaved evergreen	level 4	Broad-leaved evergreen species are greater than 50% of the tree canopy.
4122	Trees: broad-leaved semi-evergreen	level 4	Trees present are at least 25% each of broad-leaved evergreen and broad-leaved deciduous trees.
4123	Trees: broad-leaved deciduous	level 4	Trees present are at least 25% each of broad-leaved evergreen and broad-leaved deciduous trees.
4124	Tropical/subtropical, trees/shrubs in tufts on termite nests	level 4	Also called termite savannah.
413	Tall Grasslands with Shrubs	level 3	The shrub canopy must cover more than 25% of the ground.

MUC Code	Glossary of Terms in the Modified Classification Scheme	Class Level	
4131	Shrubs: broad-leaved evergreen	level 4	Broad-leaved evergreen species are greater than 50% of the shrub canopy
4132	Shrubs: broad-leaved semi-evergreen	level 4	Shrubs present are at least 25% each of broad-leaved evergreen and broad-leaved deciduous trees.
4133	Shrubs: broad-leaved deciduous	level 4	Shrubs present are at least 25% each of broad-leaved evergreen and broad-leaved deciduous trees. The area is seasonally flooded.
4134	Tropical or subtropical, trees and shrubs in tufts on termite nests	level 4	Also called termite savannah.
414	Tall Grasslands with Tuft Plants	level 3	The canopy of the tuft plants (usually palms)must cover more than 25% of the ground.
4141	Tropical Grasslands with Palms	level 4	E.g., the palm savannas of Arocomia totai and Attalea princeps north of Santa Cruz de la Sierra, Bolivia.
415	Tall Grasslands without Woody Synusia	level 3	Grasslands without trees or shrubs.
4151	Tropical Grassland	level 4	Often seasonally flooded, e.g., Compos de Varzea of the lower Amazon Valley, low latitude regions of Africa, papyrus swamps of the upper Nile Valley,.
42	Medium Tall Graminoid	level 2	The dominant grasses are 50 cm to 2 m tall when flowering or mature (greater than 50% of the herbaceous vegetation). Forbs may be present but comprise less than 50% of the herbaceous vegetation.
4210	Trees: needle-leaved evergreen	level 4	Needle-leaved evergreen species are greater than 50% of the tree canopy.
4211	Trees: broad-leaved evergreen	level 4	Broad-leaved evergreen species are greater than 50% of the tree canopy.
4212	Trees: broad-leaved semi-evergreen	level 4	Trees present are at least 25% each of broad-leaved evergreen and broad-leaved deciduous trees.
4213	Trees: broad-leaved deciduous	level 4	Trees present are at least 25% each of broad-leaved evergreen and broad-leaved deciduous trees.

MUC Code	Glossary of Terms in the Modified Classification Scheme	Class Level	
422	Medium Tall Grass Lands with Trees Covering Less than 10%	level 3	Grassland with trees covering less than 10% of the ground, with or without shrubs.
4220	Trees: needle-leaved evergreen	level 4	Needle-leaved evergreen species are greater than 50% of the tree canopy.
4221	Trees: broad-leaved evergreen	level 4	Broad-leaved evergreen species are greater than 50% of the tree canopy.
4222	Trees: broad-leaved semi-evergreen	level 4	Trees present are at least 25% each of broad-leaved evergreen and broad-leaved deciduous trees.
4223	Trees: broad-leaved deciduous	level 4	Trees present are at least 25% each of broad-leaved evergreen and broad-leaved deciduous trees.
4224	Tropical/subtropical, trees/shrubs in tufts on termite nests	level 4	Also called termite savannah.
423	Medium Tall Grasslands with Shrubs	level 3	The shrub canopy must cover more than 25% of the ground.
4230	Shrubs: needle-leaved evergreen	level 4	Needle-leaved evergreen species are greater than 50% of the shrub canopy.
4231	Shrubs: broad-leaved evergreen	level 4	Broad-leaved evergreen species are greater than 50% of the shrub canopy.
4232	Shrubs: broad-leaved semi-evergreen	level 4	Shrubs present are at least 25% each of broad-leaved evergreen and broad-leaved deciduous trees.
4233	Shrubs: broad-leaved deciduous	level 4	Shrubs present are at least 25% each of broad-leaved evergreen and broad-leaved deciduous trees. The area is seasonally flooded.
4234	Tropical or subtropical, trees and shrubs in tufts on termite nests	level 4	Also called termite savannah.
4235	Woody synusia of deciduous thorny shrubs	level 4	E.g., the tropical thorn bush savannah of the Sahel region in Africa with Acacia tortilis, A. senegal and other species.
424	Open Synusia of Tuft Plants	level 3	The canopy of the tuft plants (usually palms)must cover more than 25% of the ground.

MUC Code	Glossary of Terms in the Modified Classification Scheme	Class Level	
4241	Subtropical open palm groves	level 4	E.g., Corrientes, Argentina. Some areas are seasonally flooded, e.g., Mauritia palm groves in the Colombian and Venezuelan Ilanos.
425	Medium Tall Grasslands without Woody Synusia	level 3	Medium tall grasslands without trees or shrubs.
4251	Mainly sod grasses	level 4	Perennial, much branched creeping grass which binds the sand or soils with its root system. E.g., St. Augustine grass (Stenotaphrum secundatum), the tall-grass prairie in eastern Kansas, or the sandy soil or dunes, e.g., communities of Andropogon hallii in the Nebraska Sand Hills. In some locations the grassland is wet or flooded most of the year, e.g., Typha swamps. If that is the case classify as a wetland. See class 6.
4252	Mainly bunch grasses	level 4	Grasses which chiefly grow in tufts forming an irregular, textured surface. E.g., the hard tussock (*Festuca novae-zelandiae*) grasslands in New Zealand.
43	Short Graminoid	level 1	The dominant grasses are less than 50 cm tall when flowering or mature (more than 50 of the herbaceous vegetation). Forbs may be present but they less than 50% of the herbaceous vegetation.
431	With Trees Covering 10-40%	level 3	May be with or without shrubs. This is somewhat like a very open woodland with a more or less continuous ground cover (over 60%) of short graminoids.
4310	Trees: needle-leaved evergreen	level 4	Needle-leaved evergreen species are greater than 50% of the tree canopy.
4311	Trees: broad-leaved evergreen	level 4	Broad-leaved evergreen species are greater than 50% of the tree canopy.
4312	Trees: broad-leaved semi-evergreen	level 4	Trees present are at least 25% each of broad-leaved evergreen and broad-leaved deciduous trees.
4313	Trees: broad-leaved deciduous	level 4	Trees present are at least 25% each of broad-leaved evergreen and broad-leaved deciduous trees.
432	Short Grass Lands with Trees Covering Less than 10%	level 3	Grassland with trees covering less than 10% of the ground, with or without shrubs.
4320	Trees: needle-leaved evergreen	level 4	Needle-leaved evergreen species are greater than 50% of the tree canopy.

MUC Code	Glossary of Terms in the Modified Classification Scheme	Class Level	
4321	Trees: broad-leaved evergreen	level 4	Broad-leaved evergreen species are greater than 50% of the tree canopy.
4322	Trees: broad-leaved semi-evergreen	level 4	Trees present are at least 25% each of broad-leaved evergreen and broad-leaved deciduous trees.
4323	Trees: broad-leaved deciduous	level 4	Trees present are at least 25% each of broad-leaved evergreen and broad-leaved deciduous trees.
4324	Tropical/subtropical, trees/shrubs in tufts on termite nests	level 4	Also called termite savannah.
433	Short Grasslands with Shrubs	level 3	The shrub canopy must cover more than 25% of the ground.
4330	Shrubs: needle-leaved evergreen	level 4	Needle-leaved evergreen species are greater than 50% of the shrub canopy.
4331	Shrubs: broad-leaved evergreen	level 4	Broad-leaved evergreen species are greater than 50% of the shrub canopy.
4332	Shrubs: broad-leaved semi-evergreen	level 4	Shrubs present are at least 25% each of broad-leaved evergreen and broad-leaved deciduous trees.
4333	Shrubs: broad-leaved deciduous	level 4	Shrubs present are at least 25% each of broad-leaved evergreen and broad-leaved deciduous trees. The area is seasonally flooded.
4334	Tropical or subtropical, trees and shrubs in tufts on termite nests	level 4	Also called termite savannah.
4335	Woody synusia of deciduous thorny shrubs	level 4	The dominant grasses are less than 50 cm tall when flowering or mature (more than 50 of the herbaceous vegetation). The canopy of deciduous thorny shrubs must cover more than 25% of the ground.
434	Short Grasslands with Tuft Plants	level 3	The canopy of the tuft plants (usually palms)must cover more than 25% of the ground.
4341	Open Synusia of Tuft Plants, subtropical with open palm groves	level 4	The dominant grasses are less than 50 cm tall when flowering or mature (more than 50 of the herbaceous vegetation). The canopy of palms must cover more than 25% of the ground.

MUC Code	Glossary of Terms in the Modified Classification Scheme	Class Level	
435	Mainly Bunch Grasses with Woody Synusia	level 3	Grasses which grow in tufts, with woody plants interspersed.
4351	Tropical alpine with tuft plants	level 4	This grassland often contains Espeletia, Lobelia, Senecio and microphyllous dwarf-shrubs and cushion plants, often with woolly leaves. Above the timberline in low latitudes: Paramo and related vegetation types without snow in the alpine regions of Kenya, Colombia, Venezuela, etc.
4352	Tropical alpine, very open, without tuft plants	level 4	In these grasslands there is frequent nocturnal snowfall (though the snow is gone by 9 a.m.), the Super-Paramo (i.e. above Paramo) of J. Cuatrescasas.
4353	Tropical or subtropical alpine bunch grass, with open stands of evergreen	level 4	This grassland may also have deciduous shrubs and dwarf shrubs, e.g., Puna south of Oruro, Bolivia.
4354	Bunch grass with dwarf shrubs	level 4	Cushion plants may also grow in this grassland , e.g., Puna south of Oruro, Bolivia.
436	Short Grasslands, without Woody Synusia	level 3	Short grasslands without trees or shrubs.
4361	Short-grass communities	level 4	These communities may fluctuate in structure and floristic composition due to greatly fluctuating precipitation of the semi-arid climate, e.g., short-grass (*Bouteloua gracilis* and *Buchloe dactyloides*) prairie of eastern Colorado.
4362	Bunch-grass communities	level 4	E.g., blue tussock (Poa cloensoi) communities of New Zealand, and alpine dry Puna with Festuca orthophylla of northern Chile and southern Bolivia.
437	Short to Medium Tall Mesophytic Communities	level 3	Meadows
4371	Sod grass communities	level 4	The grassland is often rich in forbs, and occur in lower altitudes with a cool, humid climate in North America and Eurasia. Many plants may remain at least partly green during the winter, even below the snow in the higher latitudes.
4372	Alpine, subalpine meadows	level 4	These grasslands are usually moist much of the summer due to melt water, e.g., Olympic Peninsula, Washington, and the Rocky Mountains of Colorado.
44	Forb Vegetation	level 2	The plant community is dominated by broad-leaved herbaceous plants (all plants except grasses) such as clover, sunflowers (Helianthus), ferns, milkweeds (Asclepias). Forbs cover more than 50% of the herbaceous area. Grasses may be present but cover less than 50%.

MUC Code	Glossary of Terms in the Modified Classification Scheme	Class Level	
441	Tall Forb Communities	level 3	The dominant forb growth forms are more than 1 meter tall when fully developed.
4411	Fern thickets	level 4	Ferns occur sometimes in nearly pure stands, especially in humid climate, e.g., *Pteridium aquilinum*.
4412	Mainly annual forbs	level 4	Annual forbs, which germinate in the beginning and die at the end of each growing season, are the dominant (greater than 50% coverage) form.
442	Low Forb Communities	level 3	These communities are dominated by forbs less than 1 meter tall when fully developed.
4421	Mainly perennial flowering forbs and ferns	level 4	Some part of the plant is alive all year round. E.g., *Celmisia* meadows in New Zealand and the Aleutian forb meadows in Alaska.
4422	Mainly annual forbs	level 4	Annual forbs, which germinate in the beginning and die at the end of each growing season, are the dominant (greater than 50% coverage) form.. There are several types of low annual forbs. *Ephemeral forb communities in tropical and subtropical regions :* Forbs grow with very little precipitation where, from autumn to spring, clouds moisten vegetation and soil, e.g., in the coastal hills of Peru and northern Chile. The dry season aspect is desert-like. *Ephemeral or episodical forb communities of arid regions:* The " flowering desert" consists of mostly fast growing forbs, sometimes concentrated in depressions where water can accumulate in shrub or dwarf shrub formations of arid regions, e.g., the Sonoran Desert.

MUC Code	Glossary of Terms in the Modified Classification Scheme	Class Level	
5	Barren Land	level 1	Land with less than 40% vegetative cover. Barren land has a limited ability to support life, and is usually made up of thin soil, sand, or rocks.
51	Dry Salt Flats	level 2	Occur on flat floored bottoms of interior desert basins. A high concentration of salts are present due to extensive water evaporation.
52	Sandy Areas	level 2	Accumulations of sand/gravel, i.e., beaches or dunes.
53	Bare Rock	level 2	Exposed bedrock, desert pavement, scarps, talus slides, volcanic material, rock glaciers and other accumulations of rock without vegetative cover.
54	Perennial Snowfields	level 2	Accumulations of snow and ice that did not entirely melt during the previous summer, occurring where the daily average temperature is 32 F (0 C) in the warmest summer months.
55	Glaciers	level 2	Snow compacted into firn and finally to ice under weight of successive annual accumulations. Re-frozen melt water contributes to increasing density of the glacial ice mass. All glaciers exhibit evidence of present or past motions (moraines, crevasses, etc.).
56	Other Barren Cover	level 2	Dirt, gravel, other loose rock, etc.
6	Wetland	level 1	Marshes, swamps, bogs and other types of wetlands which are periodically or constantly saturated during the growing season. This periodic or constant saturation produces soils with special chemical characteristics and vegetation specifically adapted to wet conditions. The area must have greater than 40% vegetative cover to be classified as a wetland.
61	Riverine	level 2	Wetlands adjacent to a fresh water river channel (Riparian wetlands).
62	Palustrine	level 2	Wetlands dominated by trees, shrubs, persistent emergents (plants), mosses, lichens, etc. The wetlands surround water that is less than 1 hectare in size, has no active channel or tide, is less than 2 meters deep, and has low salinity. This water should be included as part of the wetland.

MUC Code	Glossary of Terms in the Modified Classification Scheme	Class Level	
63	Estuarine	level 2	Wetlands occurring adjacent to a tidal channel, or in and adjacent to the intertidal zone. An estuary is a water passage where the tide meets the current of a stream. Deepwater tidal habitats and adjacent tidal wetlands are usually semi-enclosed by land but have open, partially obstructed, or sporadic access to ocean water (at least occasionally diluted by freshwater runoff from the land).
64	Lacustrine	level 2	Wetlands surrounding open water (i.e., ponds and lakes) that are greater than 1 hectares in size and greater than 2 meters deep.
7	Open Water	level 1	Lakes, ponds, rivers and oceans. The surface of the land is continually submerged by water greater than 2 meters deep and at least one hectare in size; or continually submerged in an actively flowing channel or subtidal zone. Water should cover greater than 60% of the area, if trees and emergent plants and cover greater than 40% of the area, see wetland categories in class 6.
71	Fresh Water	level 2	Lakes, ponds, and rivers with low salinity.
72	Marine	level 2	Open ocean overlying the continental shelf or an actively flowing tidal channel.
8	Cultivated Land	level 1	The ground is covered by greater than 60% non-native cultivated species (e.g., agricultural crops, cultivated short grasses, lawns) and usually can be distinguished by the regular geometric patterns created by the lawns and fields.
81	Agriculture	level 2	Land is used for growing crops, orchards, horticulture, feeding livestock, and other agriculture.
811	Row Crop or Pasture	level 3	Examples include; corn, wheat, cow pastures, fallow fields, cultivated cranberry bogs and rice fields.
812	Orchard or Horticulture	level 3	Examples include; apple orchards, vineyards, tree nurseries.

MUC Code	Glossary of Terms in the Modified Classification Scheme	Class Level	
813	Confined Livestock Feeding	level 3	These areas are found on large farms and are used for feeding beef cattle, dairy cows (with confined feedlots), hogs and poultry.
814	Other Agriculture	level 3	Examples include; corrals, and breeding and training facilities on horse farms.
82	Non-agriculture	level 2	Land is used for parks, playing fields, cemeteries, and golf courses.
821	Parks and Playing Fields	level 3	Examples include; baseball diamonds, soccer fields, play grounds, and parks.
822	Golf Courses	level 3	
823	Cemeteries	level 3	
824	Other Non-agriculture	level 3	Any other non-agricultural cultivated areas that do not fit into classes 821, 822 or 823 (parks and playing fields, golf courses, or cemetaries).
9	Urban	level 1	Areas developed for residential, commercial, industrial, or transportation uses. Must be greater than 40% urban land cover.
91	Residential	level 2	At least 50% of the urban land cover consists of residential property (i.e., apartments, private dwellings, etc.)
92	Commercial/Industrial	level 2	At least 50% of the urban land cover consists of commercial or industrial property (i.e., businesses, factories, warehouses, etc.)
93	Transportation	level 2	At least 50% of the urban land cover consists of transportation routes (i.e., roads, highways, railroads, airport runways).
94	Other	level 2	At least 50% of the urban land cover consists of devloped areas that do not fit into residential, commercial, or transportation categories.
Misc. Definitions	Boreal		Also called cold temperate zone has a climate with cool wet summers and cold winters lasting more than six months.

MUC Code	Glossary of Terms in the Modified Classification Scheme	Class Level	
	Bryophyte		Non-flowering plants (mosses & liverworts) characterized by rhizoids rather than true roots.
	Caespitose		Arranged or combined in a thick mat or clumps, having a low stem forming a dense turf or sod, growing in clusters.
	Canopy		Uppermost layer of vegetation detected by satellite sensors.
	% Cover vs. % Species Composition		The level one classification is determined by the overall canopy or ground coverage of the entire area being classified. The level two classification is determined by the percent species composition only of the dominant level one cover type. Level 3 and 4 are more specific combinations of different species and plant communities. Example: An area is comprised of 80% herbaceous vegetation (of that 45% are forbs and 55% are grasses greater than 2 meters tall), and 20% broad-leaved evergreen trees. The classification codes are as follows: MUC level 1: 4-herbaceous vegetation. It is clearly the dominant cover type, since it covers greater than 60% of the area. MUC level 2: 41. The dominant species are grasses greater than 2 meters tall (they comprise more than 50% of the dominant cover type herbaceous vegetation). MUC level 3: 411. Trees cover 20% of the area. MUC level 4: 4111. The trees are a broad-leaved evergreen species.
	Landscaped vegetation		Landscaped yards, playing fields, cemeteries, golf courses and other cultivated vegetated areas should be classified as cultivated land (class 8) if non-native cultivated species is greater than 60% coverage. If the buildings, roads and unnatural structures (bridges, etc.) cover greater than 40% of the land, the area should be classified as urban. If wooded residential neighborhoods have greater than 40% trees covering the ground, the area would be considered forest or woodlands (see classes 0 and 1). If it is difficult to decide upon a cover type, try to determine what would be seen by the satellite. Compare similar areas with the satellite image you receive of your schoolÕs location.
	Cold-deciduous		Plants that shed leaves during the cold season.

MUC Code	Glossary of Terms in the Modified Classification Scheme	Class Level	
	Deciduous		Vegetation that sheds its leaves at the end of the growing period or in unfavorable conditions.
	Drip tips		Extended slender tips of tropical leaves that allow water to roll of the leaf surface.
	Drought-deciduous		Plants that shed leaves during the dry season.
	Facultative		Organisms able to live and thrive under more than one set of conditions.
	Firn		Snow compacted almost to ice, glacial material.
	Forb		A broad-leaved herbaceous plant such a clover, sunflowers, ferns, and milkweeds.
	Graminoid		Grasses and grass-like plants.
	Herbaceous		Vascular plant rooted in the ground with foliage that dies back annually. The meristem (stem growth tip) is located just above or below the ground.
	Lowland forest Submontane forest Montane forest Subalpine forest		It may be necessary to consult local resources to determine the specific level 4 classification for forest cover. Vegetation will vary depending on both the latitude and the altitude.
	Mesophytic		Growing in, or adapted to, a moderately moist environment.
	Microphyllous		Having small leaves (e.g., desert plants); having leaves with a single unbranched vein.
	Obligate		Organisms restricted to a particular condition of life (that condition is essential for survival).
	Overstory		Uppermost layer of vegetation detected by satellite sensors.

MUC Code	Glossary of Terms in the Modified Classification Scheme	Class Level	
	Polar		Low precipitation distributed over the entire year. There is a short wet nightless summer and a very long, cold, dark winter.
	Sclerophyllous		Vegetation with thickened hardened foliage that is resistant to water loss (sclerophylly).
	Subpolar		Transitional between the cold temperate zone and the polar zone.
	Subtropical		From the edge of the tropical zone toward the poles, in the region of the descending air masses, which get warmer as they descend and become very dry. Rainfall is very low, and the daytime temperatures are very high because of intense solar radiation. In the winter months, however, the temperature may sink to zero at night as a result of the greater net loss of heat energy in outgoing radiation. This is the hot desert zone.
	Synusia		A layer or stratum of a community. A structural unit of a major ecological community characterized by relative uniformity of life form or of height and usually constituting a particular stratum of that community.
	Temperate		Temperate zones show greater seasonal temperature changes and can be broken down as follows: Warm temperate: scarcely any or no winter, extremely wet especially in summer. Typical temperate: (e.g., central European or coastal northeastern U.S.A) cold, short winters or a winter free of frost and with very cool summers (near the ocean). Arid temperate: large temperature contrasts between summer and winter, and little precipitation. Boreal or cold temperate: cool wet summers and cold winters lasting more than six months.
	Tropical		Lies 40 degrees to the north and south of the equator. A certain seasonal variation in the mean daily temperature is noticeable. Rainfall reaches a maximum in the summer and a dry season in the cool months. The duration of the cool season increases as the distance from the equator becomes greater, and at the same time the annual rainfall decreases.
	Understory		Layer of vegetation that grows beneath the overstory consisting of smaller trees and shrubs.

MUC Code	Glossary of Terms in the Modified Classification Scheme	Class Level	
	Wet		Vegetation or environments capable of withstanding or thriving in the presence of much rain.
	Xeromorphic		Climatic conditions favorable for the development of vegetation that is adapted to, thrives in or tolerates an environment that is poor in available moisture.
	Xerophyte		A plant which is adapted to and thrives in dry conditions.

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Glossary

atmosphere
The gaseous component of the Earth system. The mass of air surrounding the Earth.

AVHRR
Advanced Very High Resolution Radiometer. An instrument carried on NOAA polar-orbiting satellites; it observes the Earth's surface in the visible through thermal infrared regions with a pixel size of 1.1 km.

biogeochemical
Refers to the chemical interactions between the living ("bio") and physical ("geo") components of the Earth system, as in biogeochemical cycles of carbon, nitrogen, etc.

biomass
The dry weight of vegetation above a unit area of ground, often reported as grams (dry weight) per square meter.

biome
A major ecological community type (as grassland or desert).

biometrics
The statistical study of biological data.

biometry
The process of making biological measurements

biosphere
The living component of the Earth system, along with the gaseous (atmosphere), liquid (hydrosphere), and solid (geosphere) components.

canopy cover
The amount of canopy foliage above a given portion of ground is the canopy cover. This will determine the amount of sunlight that reaches that portion of ground.

classification
Sorting a group of items into well-defined and distinct subsets according to specific criteria.

clinometer
A clinometer is an instrument for measuring the angle of a change in height or elevation.

criteria
Decision rules that are used to determine into which subset an item is placed during a classification.

densiometer
A device for determining the percentage of canopy closure in a wooded environment.

dichotomous
This is a branching decision tree (decoder) characterized by successive forking into two approximately equal and contradictory divisions, which ultimately leads to only one correct outcome.

difference/error matrix
A graphic method of comparing two data sets for validation.

evapotranspiration
The return of water to the atmosphere by evaporation (from solar energy) and transpiration (plant activity.)

genus (pl. Genera)
This is an inclusive category whose species have more characteristics in common with each other than with species of other genera. Genera, therefore, are collections of closely related species.

geosphere
The solid component of the Earth system; e.g. rocks, soil, etc.

gradient
The rate of change in a measured quantity over space or time.

ground cover

The amount of ground-level vegetation covering a given area. (For the GLOBE program, "ground level" is defined as "below the observer's knees." Ground cover is expressed as a percentage. E.g. 30% ground cover means that, viewed from above, 30% of the ground surface is obscured by ground-level vegetation.

hydrosphere

The liquid component of the Earth system; e.g. oceans, lakes, rivers, etc.

multitemporal

Viewed from more than one point in time.

NOAA

The National Oceanic and Atmospheric Administration.

perennating organs

Parts of plants that live over from one season to another (tubers, rhizomes.)

perturbations

A disturbance in the normal functioning of a system.

phenology

The study of changes over time in an environmental setting.

photointerpretation

The production of a land cover map or identification of specific features by visual inspection of an aerial photo or satellite image.

photosynthetic potential

The maximum amount of biomass that can be produced in an area.

physiological

Characteristic of, or appropriate to, an organism's healthy or normal functioning.

primary productivity

The rate at which organic material is produced by photosynthesis at a given location. Often represented as grams (dry weight) of Carbon per m^2 per year.

senescence

The plant growth phase from full maturity to death that is characterized by a loss in dry weight.

species

This is a group of individual plants/ animals that is fundamentally alike.

TM

Thematic Mapper. Carried aboard the Landsat 4 and 5 satellites, this instrument is designed to study surface features in 7 bands covering the visible through thermal infrared regions with a pixel resolution of 30 m in 6 bands and 120 m in the thermal infrared band.

validation data

Data necessary to assess the accuracy of a land cover map produced by manual or electronic means.